University of Alberta

The Differential Outcomes Effect (DOE) in Spatial Localization: An investigation with adults

by

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Abstract

We investigated whether search accuracy of adults humans could be enhanced by using differential reward contingencies in spatial tasks conducted on a computer screen. We found that search accuracy could be enhanced by using differential outcomes in a spatial search task, but this differential outcomes effect (DOE) only occurred under very specific conditions. To our knowledge this is the first report of a DOE in spatial tasks and is one of only a few demonstrations that differential outcomes can enhance memory performance in normal functioning adults.

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First and foremost I would like to thank my supervisor Dr. Marcia Spetch for helping me to get to where I am today. Without her dedication, effort, and willingness to guide me through the trials and tribulations of graduate school, the journey to this point would not have been possible. Without her I would not be the student I am today. For all of these things and more, I will always be grateful.

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Sincerely,

Eric L. G. Legge

August, 2008

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The Differential Outcomes Effect (DOE) in Spatial Localization

In conditional choice experiments, using differential reinforcement for different responses has been shown to significantly improve both animal and human acquisition and accuracy compared to those who receive non-differential reinforcement (see Urcuioli, 2005 for a review). Enhancement of accuracy and acquisition has been theorized to occur because differential outcomes (DO) allow for the formation of outcome-specific expectancies by correlating different responses and procedural stimuli with different reinforcers. Thus, these reinforcer-specific expectancies provide an additional discriminative cue, which in turn increases task acquisition and overall accuracy. This enhancement of accuracy and acquisition has been termed the Differential Outcomes Effect (DOE) (Trapold, 1970; Trapold & Overmier, 1972).

Trapold (1970) was the first to propose the existence of a DOE. In his initial experiment he trained rats on a discrimination task where the experimental (DO) group had to press a lever for food following a particular auditory stimulus and another lever for liquid sucrose following a different auditory stimulus. The control group received the same type of reinforcer (i.e., half the subjects always received food pellets and half always received liquid sucrose) for pressing the correct lever for either stimulus. Trapold found that the group that received DO acquired the task faster than the group with a single, common outcome. To explain this result, Trapold and Overmier (1972) suggested that the group that received differential reinforcement (the DO group) based their decisions on both the auditory stimuli and the expectation of the type of reinforcer they were to receive. In contrast, the control group only based their decisions on the auditory stimuli. This is because the control group received only a single, common

reinforcer, and unlike the DO group, could not use the expectation of a particular reward as an additional discriminative cue to aid responding.

The DOE has been demonstrated in many species and across many conditional choice experimental paradigms (see Urcuioli, 2005; Goeters, Blakely, & Poling, 1992 for reviews). The species in which the DOE has been observed include adult humans (Estèvez et al, 2007; Mok & Overmier, 2007; Miller, Waugh, & Chambers, 2002), human children (Estèvez, Overmier, & Fuentes, 2003; Estèvez, Fuentes, Mari-Bêffa, González, & Alvarez, 2001; Maki & Overmier, 1995), rats (Honey & Hall, 1989; Fedorchak & Bolles, 1987; Kruse & Overmier, 1982; Carlson & Wielkiewicz, 1976), horses (Miyashita, Nakajima, & Imada, 2000), dogs (Overmier, Bull, & Trapold, 1971), and pigeons (Kelly & Grant, 2001; Astley, Peissig, & Wasserman, 2001; Astley & Wasserman, 1999; Jones & White, 1994; DeMarse & Urcuioli, 1993). Some of the experimental paradigms in which the DOE has been successfully produced include: matching-to-sample (Alling, Nickel, & Poling 1991a; 1991b; Jones, White, & Alsop, 1995), two choice go/no-go successive discriminations (Carlson & Wielkiewicz, 1972; Urcuioli & Zentall, 1992), and ambiguous feature discrimination (Nakajima & Kobayashi, 2000). While the bulk of evidence for the DOE has been with animals, evidence for the DOE in humans has been much more varied and scarce (see Urcuioli, 2005 for a review).

Prior to 2002, most demonstrations of the DOE in humans have been in children and individuals with mental cognitive deficits (see Urcuioli, 2005 for a review). However, in 2002 Miller et al. reported the first evidence for a DOE in normal-functioning adults. Miller et al. had participants, aged 18 – 38 years, match words to 15

different kanji characters. Participants were rewarded with entries into different prize draws and the presentation of a picture on the screen. For the DO group, prize draw entries and pictures were contingent upon particular kanji characters. In contrast, the non-differential outcomes (NO) group received the same prize draw entries and pictures, but the rewards were uncorrelated with kanji characters. Miller et al. found that the DO group was more accurate and acquired the task faster than the NO group.

Other than Miller et al.'s (2002) study, only two other successful productions of a DOE in normal functioning adults have been reported. The first, by Estèvez et al. (2007), had adult participants differentiate between the symbols "<" and ">" in mathematical statements and identify whether the statements were true or false (e.g., 1.23 > 1.22, true or false?). Initially, Estèvez et al. divided participants into two groups based on whether they had difficulty differentiating between the symbols in a pre-screening test. After participants were divided into these groups, participants in each group were further subdivided into either a DO or NO group. In their first experiment Estèvez et al. found that, in participants who initially had difficulty differentiating between the symbols, those in the DO group had significantly lower reaction times than participants in the NO group. In a second experiment, Estèvez et al. increased the difficulty of the task by introducing negative numbers to the mathematical statements participants had to evaluate (i.e., -1.84 < -1.43, true or false?). Participants that initially had difficulty differentiating between the symbols "<" and ">" had higher levels of mean accuracy when receiving DO. In both experiments there were no significant differences found between the DO and NO groups for those participants who did not

display any difficulty differentiating between the symbols "<" and ">" in the pre-screening test.

The DOE in adult humans was also reported by Mok and Overmier (2007). In their experiment, participants had to match an abstract primer image to one of four presented images. Three of the four images were distracters, while the correct image matched the primer on one of four dimensions: color, shape, angle of rotation, or depth of geometric shape. Mok and Overmier used a within-subjects design in which participants received both a task which had DO, and a task which had NO. The results showed that participants who completed the task while receiving DO had significantly higher levels of accuracy than when they did not receive DO. Thus, Mok and Overmier produced a significant DOE with human participants.

Recently, it has been suggested that the DOE may occur because different neurological pathways and structures are activated when one learns using a Differential Outcomes Procedures (DOP) rather than learning using a Non-differential Outcomes Procedure (NOP) (Savage, 2001). Research has shown that "animals with brain damage traditionally associated with explicit memory impairment *do not* display the traditional impairment on memory tasks when the [DOP] is employed" (Savage, 2001, p.192, italics added for emphasis). Additional support for the idea that the DOP and NOP use different neurological structures and pathways is the finding that the cholinergic system is required to solve memory tasks when using a NOP, however, it is not required when a DOP is used (Savage & Parsons, 1997; Savage, Pitkin, & Knitowski, 1999; Buzzetti, Kirpan, & Savage, 2001 as cited by Savage, 2001).

Further support that DOPs and NOPs use different neurological structures and paths has been shown in studies regarding hippocampal lesions and function. Recently, it was shown that hippocampal lesions dramatically impaired rats' performance on a matching-to-position task when learning occurred using a NOP. However, when learning occurred using a DOP, impairment was only minor (Savage, Buzzetti, Ramirez, 2004). Finally, evidence that the DOP and NOP use different neurological systems has also been shown by Savage, Koch, and Ramirez (2007). In their study, they trained rats using either a DOP or NOP and demonstrated that there was short-term memory (STM) enhancement in rats trained with the DOP (i.e., a DOE was produced). Additionally, when they injected the γ-aminobutyric acid $(GABA)_A$ agonist muscimol into the basolateral amydgala (BLA) they found dose-dependent impairment of STM in the DOP-trained rats, but not in the NOP-trained rats. The results from this study support the notion that the BLA is important for the formation and use of reward expectancies in a STM task while using a DOP, but not while using an NOP. These results also highlight the fact that different neurological structures and pathways are activated when learning using a DOP compared to using a NOP (Savage et al., 2007). Taken together, these studies clearly show that, compared to using a NOP, there are large differences in the neurological structures and pathways activated when using a DOP.

It is thought that the DOE is a product of associative memory; namely that participants who receive differential outcomes have an additional discriminative cue (i.e., the expectation of receiving outcome X with behavior A and outcome Y with behavior B) to aid in the recall of the necessary memory which is not available to

participants who receive either a single, common reward or uncorrelated rewards (Trapold & Overmier, 1972). Some early theories such as O'Keefe and Nadel (1978) suggested that spatial learning used a system other than associative learning. Accordingly, effects that depend on associative processes, such as the DOE, might not occur in spatial learning. However, more recent evidence suggests that many associative principles, such as overshadowing (Gray, Bloomfield, Ferry, Spetch, & Sturdy, 2005) and blocking (Pearce, Graham, Good, Jones, & McGregor, 2006), do occur in the spatial domain (see Chamizo, 2003 for a review). I therefore hypothesized that the DOE would be observable not only in working memory and conditional choice tasks, but also in the spatial domain. While there has been a great deal of research on the DOE in conditional choice and working memory tasks (see Urcuioli, 2005; Goeters et al., 1992 for reviews), to our knowledge there has been no attempt to determine whether a DOE can be produced in the spatial domain without fixed, discrete choices such as a matching-to-position task (Ramos & Savage, 2003; Savage, Pitkin, & Careri, 1999). The following experiments attempted to enhance search accuracy in adults by using DO in spatial tasks, both with and without working memory components.

Experiment 1

This experiment attempted to enhance search accuracy by using differential outcomes in a computerized spatial localization task. Participants were required to find a hidden goal relative to two different landmarks. For correctly finding the goal participants received graphical images as rewards. In the DO group, landmark and reward type were correlated, while in the NO group they were not. I hypothesized that

participants who were in the DO group would search more accurately than those in the NO group.

Method

Participants. Participants were 83 first year Psychology students (46 males, 37 females) aged 18 – 25 (M = 19.29, SD = 1.43) who were recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. Stimuli consisted of two landmarks which differed in size and color (red and yellow circles; diameter = 2.02 cm and 2.70 cm respectively) which were presented individually in random order at semi-random screen locations on a 17 inch flat-panel LCD monitor (Viewsonic VG7106). The landmark locations were semi-random because the area of the screen viable for presentation was limited so that the goal locations related to each landmark could not appear outside of the visible screen area.

The goal area was a 1.51 cm^2 square and had a static relation to each landmark. Specifically, using polar co-ordinates in which the top center of the screen is considered North, the goal location from the center of the red landmark was 3.37cm to the South and 4.22cm to the West. The goal location from the center of the yellow landmark was

6.75cm to the North (see Figure 1 for a diagram). These relations stayed the same throughout the experiment.

The rewards used in this experiment were two different bitmap images. These images were of a lime-green smiley face and a magenta star, each approximately the same size as the goal area (1.51 cm^2).

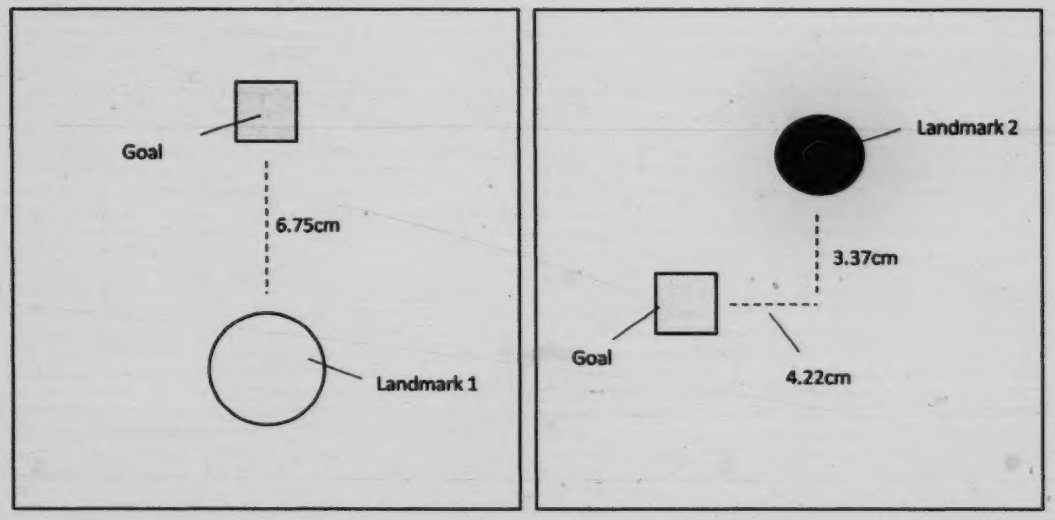

Figure 1. The distance and direction of the goal location relative to the two different landmarks in Experiment 1. Images are not to scale.

Procedure. The experiment consisted of two training phases and a testing phase. Before beginning the experiment, participants were randomly assigned to either a DO or NO group. For participants in the DO group, each landmark had a unique reward associated with it (i.e., red landmark always earned the magenta star reward; green landmark always earned the lime-green smiley face reward). For participants in the NO group, rewards were uncorrelated with landmark type (i.e., correct responses with the

red landmark would earn the magenta star for 50% of trials, and the lime-green smiley face the other 50% of trials). A two second inter-trial interval (ITI) was presented between each trial in all phases. Before each phase of the experiment, a brief instruction screen was displayed detailing what participants would have to do in the next phase.

The initial phase of training was implemented to briefly show participants where the goal area would be located in relation to each landmark, and to provide experience with the reward contingencies. This phase consisted of four trials: two with each type of landmark. In addition to the landmark being displayed on the screen, the perimeter of the goal area was also displayed and outlined with a thin white pen-line. Participants had to click within the goal area with the mouse to receive their reward and move to the next trial. When participants selected the goal area, a reward was displayed in the same location as the goal for two seconds, after which the screen was cleared and the ITI was initiated. In this phase of the experiment, participants had unlimited mouse clicks and time to find the goal.

The second phase of training was implemented to reinforce the relationship between the type of landmark presented and its associated goal location, as well as to give the participants more experience with the reward contingencies. This phase consisted of eight trials, four with each type of landmark, and was similar to the first phase of training except that the goal area was no longer outlined with a white pen-line.

The final phase was a testing phase. It consisted of 60 trials, 30 with each type of landmark. This phase was similar to the second phase of training except participants were only given one mouse click to find the goal. If participants found the goal on their first mouse click they received a reward; if they did not a text-box reading "Incorrect"

was displayed in the center of the screen. Also, a tally was displayed at the bottom of the screen at the same time as participants received the reward or the "Incorrect" text-box. This information gave participants a tally of the rewards they had received throughout the experiment. At the end of testing, a thank you screen was presented and participants were debriefed (see appendix E for an example debriefing form).

Results

Only data from the testing phase of the experiment was considered for analysis. Accuracy was highly similar in the two groups. Participants in the DO group ($n = 43$) had a mean error[1] of .13, while participants in the NO group ($n = 40$) had a mean error of .14. Levene's Test for Equality of Variances was significant, $F(1, 81) = 3.99$, $p < .05$. Therefore, equal variances between groups were not assumed for the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on participants' mean error, $t(67.44) = .72$, $p > .05$.

[1] Mean error is operationally defined as (1 – proportional mean accuracy). Mean error is the proportion of trials in a given phase on which participants were incorrect.

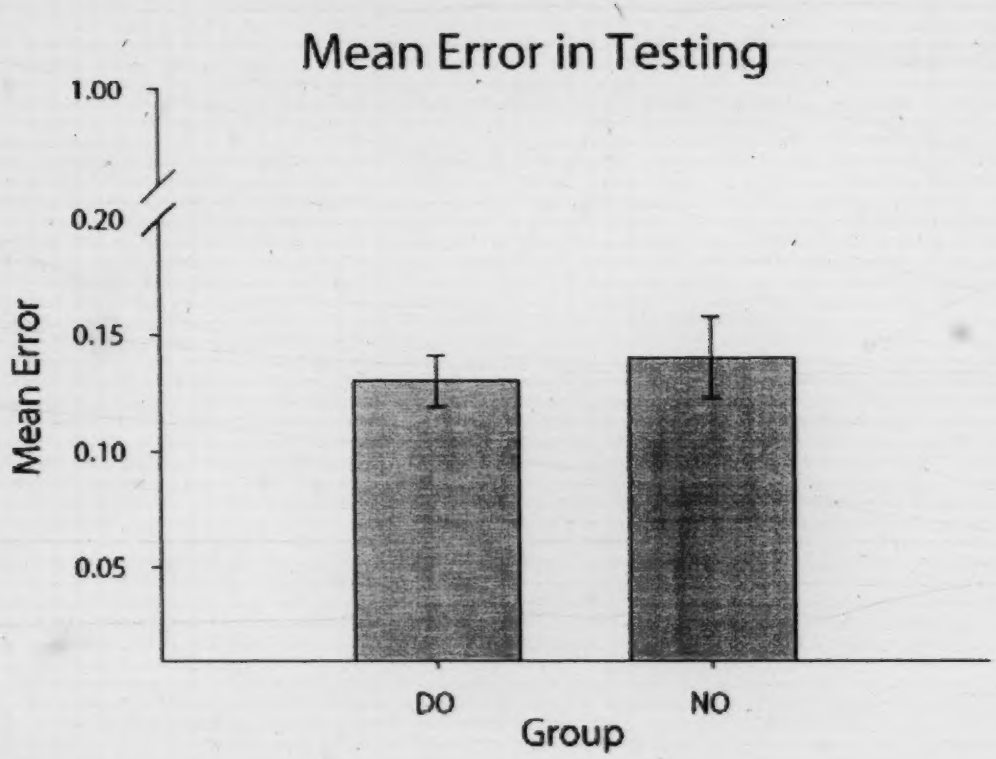

Figure 2. Proportion of mean error in testing for both the DO (*dark gray bar*) and NO (*light gray bar*) groups in Experiment 1. Error bars represent standard error of the mean.

Discussion

Differential outcomes did not significantly enhance search accuracy in spatial localization. In this experiment, both DO and NO groups had highly similar levels of error in testing. Two possible explanations for this are: 1) search accuracy cannot be enhanced by using differential outcomes in a spatial localization task, or 2) there were features of our experimental design which precluded a significant enhancement of search accuracy when using differential outcomes in the spatial localization task. I believed that the latter was more likely; specifically, that the rewards were not very salient for participants. It was likely that in this experiment both rewards were treated as equivalent by participants and this was why I did not observe an enhancement of search accuracy using differential outcomes in the spatial localization task. Unlike many of the animal studies in which the DOE has been observed, there is normally a significantly different fitness cost between different rewards (e.g., different probabilities and types of food reinforcement). However, in the present experiment, there was no such cost between earning one graphical image compared to another. I attempted to correct this in Experiment 2.

Experiment 2

When the results of Experiment 1 did not show enhancement of search accuracy when using differential outcomes in a spatial localization task, I hypothesized the low saliency and similarity of the rewards precluded the production of a DOE. Therefore, in Experiment 2 I increased the saliency of the rewards by using more familiar and meaningful images; namely images of different Canadian coins. I also provided the

opportunity for participants to earn monetary rewards for their performance. I hypothesized that the higher saliency, as well as the differential value of the rewards, would prevent participants from treating both rewards as equivalent. Therefore, I expected that using monetary instead of graphical rewards would correct the problems outlined in Experiment 1, and thus allow for an increase in search accuracy when using differential outcomes in the spatial domain.

Method

Participants. Participants were 55 first year Psychology students (27 males, 28 females) aged 17 – 38 (M = 19.69, SD = 3.37) who were recruited from the University of Alberta's research participation pool. Participants received partial course credit and a variable monetary reward (maximum $3.30 Canadian Dollars) for participating in the experiment. The exact reward participants received depended on their overall performance in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. Experiment 2 used the same materials and apparatuses as Experiment 1 with the following exceptions. First, participants received images of different Canadian coins as rewards. The coins were either dimes (value = $0.10 CDN) or pennies (value = $0.01 CDN) and the images were 2.02 cm^2 in size. Second, participants would receive the accumulated total of the coins they had earned in testing at the end of the experiment. Third and finally, the tally presented at the bottom of the

screen during testing now displayed the number of dimes and pennies participants had received, as well as the total value of the rewards earned.

Procedure. The procedure of this experiment was the same as Experiment 1 with the following exception: participants earned monetary rewards for their performance in testing. Specifically, participants would earn the total monetary value of the reward images they received in testing (maximum value = $3.30).

Results

Only the mean error data from the testing phase of the experiment was considered for analysis. Mean error was similar for both groups. Participants in the DO group (n = 27) had a mean error of .20, while participants in the NO group (n = 21) had a mean error of .27. Levene's Test for Equality of Variances was not significant, $F(1, 46) = .46$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant difference between groups in mean error, $t(46) = 1.57$, $p > .05$.

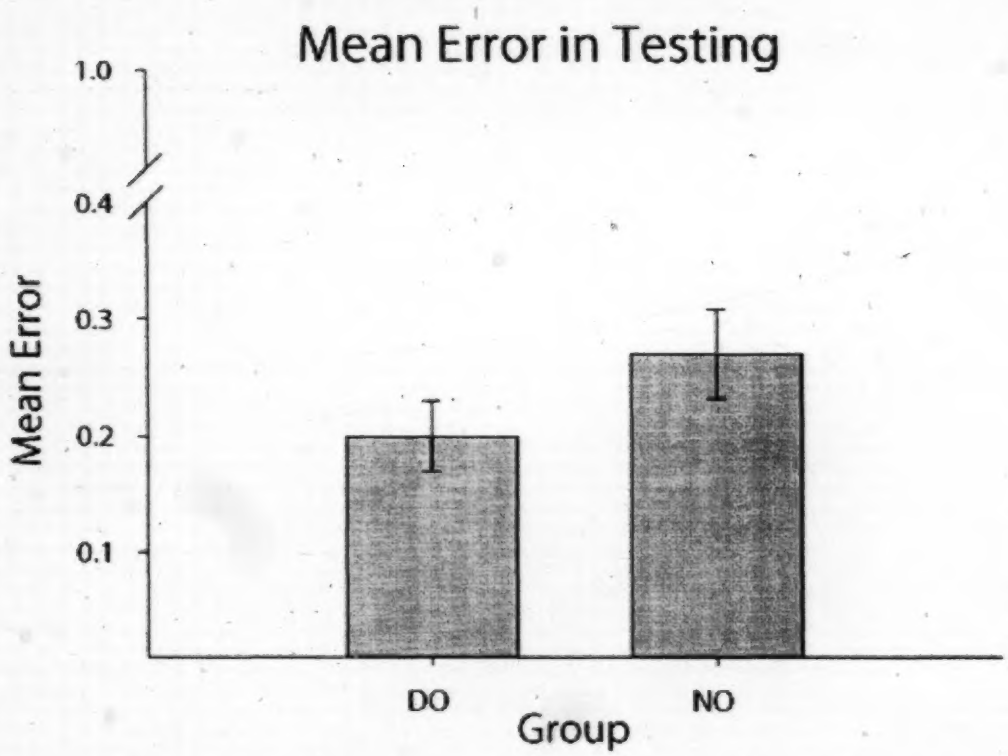

Figure 3. Proportion of mean error in testing for both the DO (*dark gray bar*) and NO (*light gray bar*) groups in Experiment 2. Error bars represent standard error of the mean.

Discussion

Similar to Experiment 1, there was no evidence for the significant enhancement of search accuracy when using differential outcomes in the spatial domain. One commonality between Experiment 1 and this experiment is that participants in both groups made relatively few errors. The high levels of accuracy may be indicative of a ceiling effect which could be attenuating any differences between groups. It is possible that in order for a significant DOE to occur in the spatial domain, the task must be sufficiently difficult so that the effect is not masked by ceiling accuracy.

Alternatively, it may be that a DOE can only be observed when a task contains a strong working memory component. Much of the literature to date that have shown a significant DOE used tasks which contain a strong working memory component (see Urcuioli, 2005; Goeters et al, 1992 for reviews). To investigate these hypotheses, I devised Experiment 3.

Experiment 3

In Experiment 3, I increased the task difficulty and dependence on working memory. Task difficulty was increased by having only a single landmark with four possible goal locations. Each of the goal locations were contingent on a particular primer, displayed prior to the presentation of the landmark, which indicated which goal location was active on that trial. This new design increased the task's reliance on working memory and its level of difficulty relative to Experiments 1 and 2. In the current task, participants had to remember which primer was displayed in addition to the goal location that was contingent on that particular primer. To enhance the saliency of the rewards, differential auditory feedback were incorporated in conjunction with different graphical rewards.

Method

Participants. Participants were 42 first year Psychology students (17 males, 25 females) aged 17 – 23 (M = 19.02, SD = 1.60) recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal

vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. This experiment was conducted in the same testing room and on the same computers as Experiments 1 and 2. However, for this experiment, headphones (Philips SHP2500) were also attached so that participants could receive auditory feedback.

There were four categories of stimuli: primer images, landmarks, goal areas and reward stimuli. Primers consisted of four gray, abstract 3D images called atoms (see Vuong & Tarr, 2004; 2006 for more detail) which were presented in the center of the screen against a black background. These images were approximately 8.43 cm^2 in size (see Figure 4 for images of the primers used).

The landmark in this experiment was a single, opaque white circle (diameter = 2.02cm). It appeared on the screen in a semi-random location, limited so that it, or the goal locations associated with it, could not appear outside the visible screen area. The goal area was a 1.51 cm^2 square. There were four possible locations in which the goal could be hidden relative to the landmark. Each goal location was contingent on one of the four primers. Specifically, from the center of the landmark, the goal area was 4.22cm South and 2.02cm West following primer 1, 6.75cm South following primer 2, 3.37cm South and 1.69cm to the East following primer 3, and 5.06cm South and 4.22cm to the East following primer 4 (see Figure 5 for a diagram of where these locations were relative to the landmark).

Rewards were graphical images (approximately 2.02cm^2 in size) in conjunction with sound clips. The graphical rewards were images of items university students commonly misplace: a cell phone, wallet, keys, and student ID card. Using these rewards were hypothesized to be more salient than those graphical rewards used in Experiments 1 and 2 because they are of items students commonly misplace and spend time looking for in everyday life. These images appeared in the location of the hidden goal area. To further enhance the saliency of rewards for participants, a sound clip associated with the graphical reward image was played when participants correctly selected the goal area during a trial. All sound clips were approximately 1.5 seconds in duration. Each graphical reward image had a particular sound clip associated with it in both the DO and NO groups. The graphical reward image and sound clip pairings were as follows: the cell phone's associated sound clip was of a cell phone ringing, the wallet's was the sound of an old fashioned cash register opening, the keys' was the sound of keys being shaken, and the student ID card was the voice of a person saying "excellent!". If the participant was incorrect on a particular trial, they received the "incorrect" feedback, which consisted of the correct graphical reward image being displayed in the goal area, but with a different sound clip. This sound clip was of a buzzer, similar to those of television game shows.

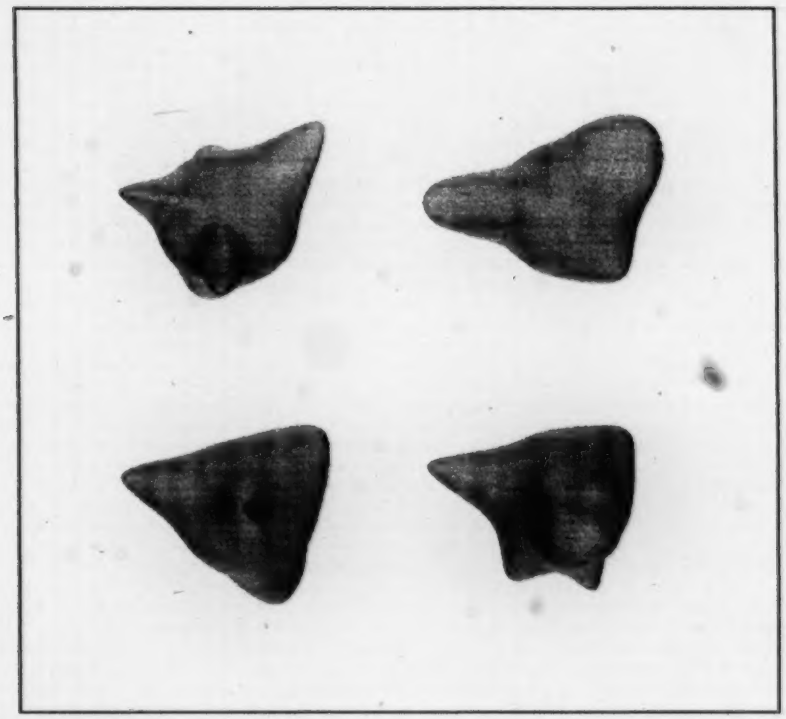

Figure 4. Primers used in Experiment 3.

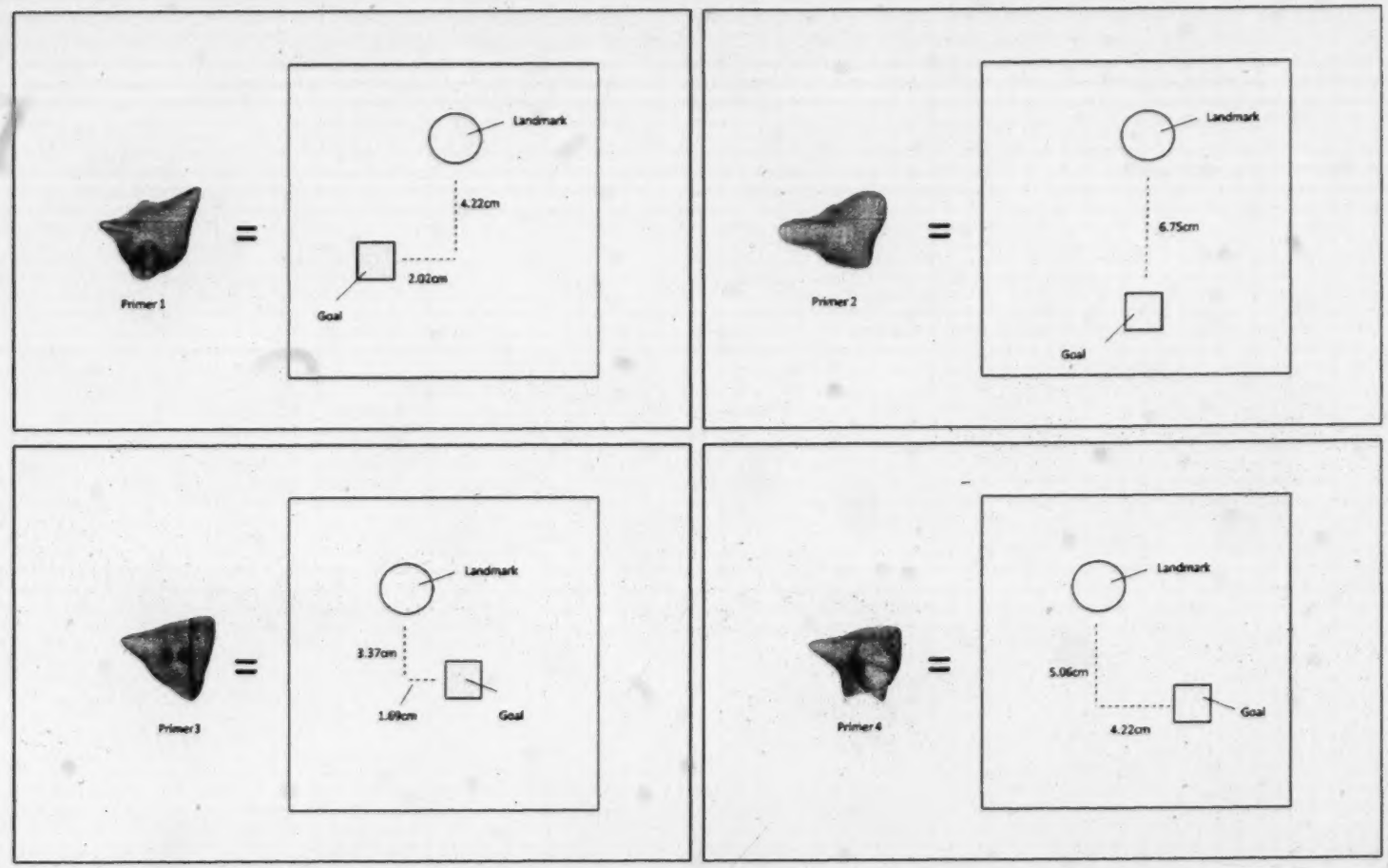

Figure 5. Active goal locations relative to the common landmark for each primer type in Experiment 3. Images are not to scale.

Procedure. The experiment consisted of three training phases and a testing phase. Participants were randomly selected to be in either the DO or NO group, and response contingencies for each group remained the same as the previous two experiments. Before beginning the experiment, participants were read a brief set of instructions by the experimenter and listened to a sample music clip to adjust the volume of their headphones to a comfortable level. At the start of the experiment, instructions presented on the computer screen detailed what the participant needed to do to complete the first phase of training. Additional instruction screens proceeded each remaining phase of the experiment (see Appendixes B and C for the wording of the instructions).

The initial training phase consisted of 16 trials. In this phase, the landmark was displayed in a semi-random position on the screen in conjunction with its associated goal area. The goal area was also visible and its perimeter was outlined in black. Participants had to click within the goal area with the mouse to earn their reward and advance to the next trial. In this phase, participants had unlimited mouse clicks and time to click within the goal area. Rewards were presented for 1.5 seconds, followed by a two second ITI before starting the next trial. Rewards were presented for correct selections and followed the contingencies dictated by which group the participant was in (i.e., DO or NO). To help participants learn the relation between the primer and the goal location associated with it, a miniaturized version of the primer image was presented on the screen in the top left-hand corner and remained there for the duration of the trial.

After the first training phase, participants progressed to the second training phase. There were 16 trials in this phase and the primers were no longer displayed in the top left-hand corner of the screen. Instead, the primers were presented in the center of the screen without the landmark for two seconds, after which the screen would be cleared. After the screen was cleared, the landmark was presented in a semi-random screen location and participants were required to click within the goal area within 30 seconds or the trial was scored as incorrect. In this phase, the goal area was still outlined in black and participants had unlimited mouse clicks to find the goal. If participants were incorrect on a trial (i.e., they took over 30 seconds to click within the goal area), they were presented with the incorrect feedback as detailed in the Materials and Apparatus section of this experiment. This phase was designed to give participants more experience associating the goal locations with particular primers.

The third training phase of the experiment was the same as the second phase of training with the following exceptions. First, the black outline of the goal area was no longer visible. Second, this phase consisted of 48 trials. This phase of training was included to give participants experience finding the goal location associated with particular primers without having a visible goal location to guide their search behavior. After completing this phase of training, participants proceeded to the testing phase of the experiment.

The testing phase was the same as the third training phase with the following exceptions. First, participants had only one mouse click to find the goal. If participants did not correctly select the hidden goal area on their first mouse click, they were scored as incorrect and received the incorrect feedback and correction procedure as described

in the second phase of training. Second, a two second Retention Interval (RI) was incorporated between the disappearance of the primer and the presentation of the landmark. Third and finally, a tally screen was displayed after feedback was presented. The tally screen was displayed for two seconds before the ITI was initiated and gave participants a detailed listing of each reward they had earned throughout testing. After completing this phase of the experiment, participants were presented with a final tally screen detailing their performance and were debriefed (see Appendix E for an example of a debriefing participants received).

Results

Mean Error. Participants in the DO group had significantly lower levels of mean error in both the final phase of training and testing than participants in the NO group. Two separate independent samples t-tests were conducted: one on the mean error of participants' first choice (i.e., mouse click) in the final phase of training, and one on participants' mean error in testing.

In the final phase of training, mean error on the first mouse click for participants in the DO group ($n = 21$) was .60, while mean error on the first mouse click for participants in the NO group ($n = 21$) was .82. Levene's test for Equality of Variances was not significant $F(1, 40) = .00, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed a significant effect of group on the mean error of participants' first choice, $t(40) = 3.27, p < .05$.

In testing, mean error for participants in the DO group was .34, while participants in the NO group had a mean error of .58. Levene's test for Equality of Variances was significant, $F(1, 40) = 34.47$, $p < .05$. Therefore, equal variances were not assumed in the subsequent independent samples t-test. The independent samples t-test revealed a significant effect of group on mean error, $t(29.47) = 2.74$, $p < .05$.

Mean Deviation from Goal. In the final phase of training, mean deviation from the goal did not differ between groups. However in testing, participants' mouse clicks in the DO group were significantly closer to the goal than those in the NO group. Two separate independent samples t-tests were conducted: one on the mean deviation from the goal of participants' choices (i.e., the spread of mouse clicks) in the final phase of training, and one on participants' mean deviation from the goal in testing. All measurements in this analysis are the mean deviation of participants' first mouse click in centimeters from the center of the goal area.

In the final phase of training, the mean deviation of participants in the DO group was .96cm from the goal, while participants in the NO group had a mean deviation of 1.40cm from goal. Levene's test for Equality of Variance was not significant, $F(1, 40) = 1.22$, $p > .05$. Therefore, the amount of variance between groups was considered equal for the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on participants' mean deviation from the goal, $t(40) = -1.58$, $p > .05$.

In testing, the mean deviation from the goal in the DO group was .83cm, while the NO group had a mean deviation of 2.10cm from the goal. Levene's test for Equality

of Variance was significant, $F(1, 40) = 112.10$, $p < .05$. Therefore, equal variances between groups were not assumed for the subsequent independent samples t-test. The independent samples t-test revealed a significant effect of group on participants' mean deviation from the goal, $t(40) = -3.64$, $p < .05$.

Mean Number of Mouse Clicks to Find the Goal. The number of mouse clicks participants made before they either found the goal or timed out in the final phase of training was significantly different between the DO and NO groups. In the DO group, the mean number of mouse clicks required by participants to find the goal was 9.37, while in the NO group participants required a mean of 24.23 mouse clicks to find the goal. Levene's test for equality of variances was significant, $F(1, 40) = 17.45$, $p < .05$. Therefore, equal variances were not assumed in the subsequent independent samples t-test. The independent samples t-test revealed a significant effect of group on the number of mouse clicks required by participants to find the goal, $t(40) = -3.39$, $p < .05$.

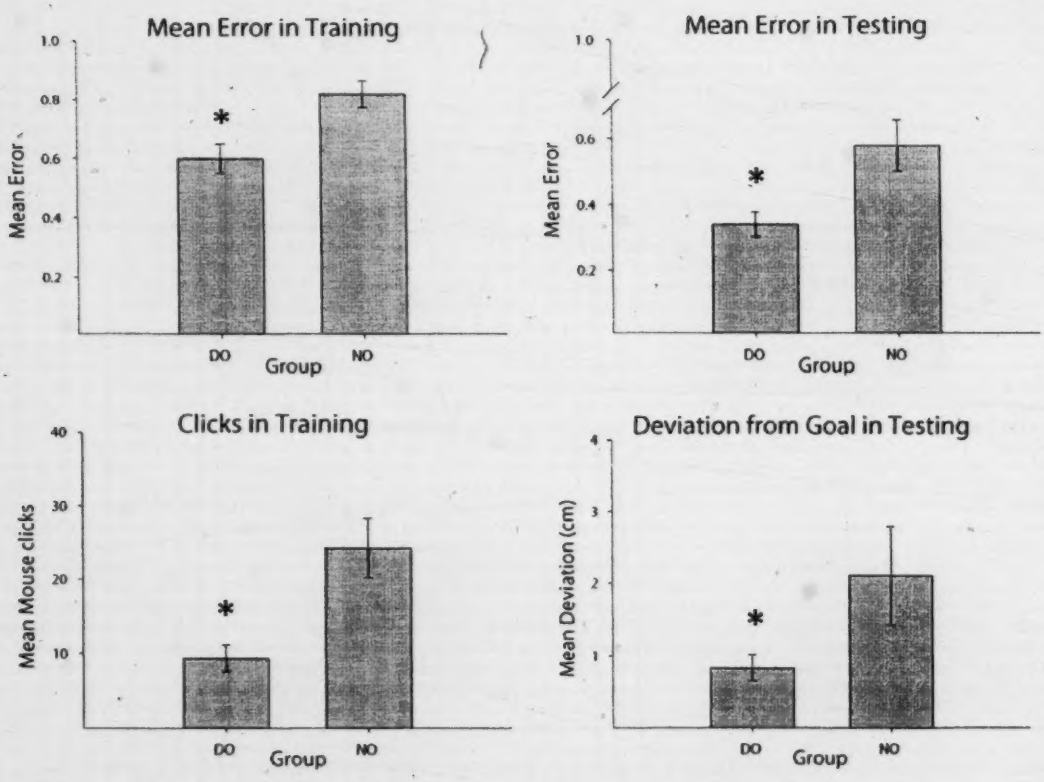

Figure 6. Graphical representations of proportional means and standard errors for the error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 3. Error bars represent standard error of the mean. An asterisk (*) above the DO bar indicates that the DO group differed significantly from the NO group in that statistical analysis ($p < .05$).

Table 1

Summary of Results from Experiment 3.

Measure	Phase of Program	t-statistic	Significant[b] ($p < .05$)?
Mean Error	Training	3.27	Yes[a]
	Testing	2.74	Yes[a]
Mean Deviation from the Goal	Training	-1.58	No
	Testing	-3.64	Yes[a]
Mean Number of Mouse Clicks	Training	-3.39	Yes[a]

[a]DO group has significantly less (measure type) than the NO group.
[b]All statistical tests were two-tailed tests.

Discussion

In this experiment, a significant enhancement of search accuracy in the spatial domain was observed when differential outcomes were used. Specifically, participants in the DO group were significantly more accurate and deviated significantly less from the goal in testing than those in the NO group. Furthermore, a significant DOE was also observed in training: participants in the DO group were significantly more accurate and required fewer mouse clicks to find the goal than those in the NO group. The only measure in which performance did not differ significantly between groups was the mean deviation from the goal in the final phase of training. However, this was an aggregate measure taken across all mouse clicks on a given trial and reflects the fact that participants in both groups homed in on the goal area when given unlimited mouse clicks.

To our knowledge, this is the first production of a DOE in a spatial localization task, and demonstrates that the DOE can be produced in tasks other than the conditional choice paradigm. However, it is unclear whether the increase in task difficulty, the addition of a more demanding working memory component, or a combination of both were critical determinants of the DOE.

Experiment 4A

Although the significant increase in task difficulty in Experiment 3 may have been the reason for the DOE, it also could have been the incorporation of the working memory component (i.e., remembering which primer was displayed to know where to search). In Experiment 4a, I returned to a pure spatial localization design, similar to those used in Experiments 1 and 2. Thus, the explicit working memory components used in Experiment 3 were removed (e.g., the primers, common landmark, and RIs). To avoid ceiling effects similar to those seen in Experiments 1 and 2, I increased the difficulty of the task by adding two additional landmarks with different goal locations and rewards. Furthermore, I also reduced the number of training trials given to participants. If the DOE observed in Experiment 3 depended solely on the increase of task difficulty from Experiments 1 and 2, then I should see a DOE in this experiment as well.

Method

Participants. Participants were 40 first year Psychology students (8 males, 32 females) aged 17 – 33 (M = 19.75, SD = 3.34) recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. Participants were tested in the same room and with the same computer equipment that was used in Experiment 3. Rewards, both images and sound clips, were also the same as those used in Experiment 3. However, unlike Experiment 3, this experiment contained four distinct landmarks and did not contain primer images.

Landmarks consisted of four different graphical stimuli: a cyan square (sides = 1.01cm), a yellow diamond (sides = 1.01cm), a green equilateral triangle (sides = 1.01cm), and a white circle (diameter = 2.02cm). The goal area was a 1.52cm^2 square and was located a different distance and direction away from each landmark. Specifically, the goal area was 4.22cm South and 2.02cm to the West of the cyan square landmark, 6.75cm South of the yellow diamond landmark, 3.37cm South and 1.67cm East of the green triangle, and 5.06cm south and 4.22cm to the East of the white circle (See Figure 7 for a diagram). All measurements were from the center of the landmark to the center of the goal area.

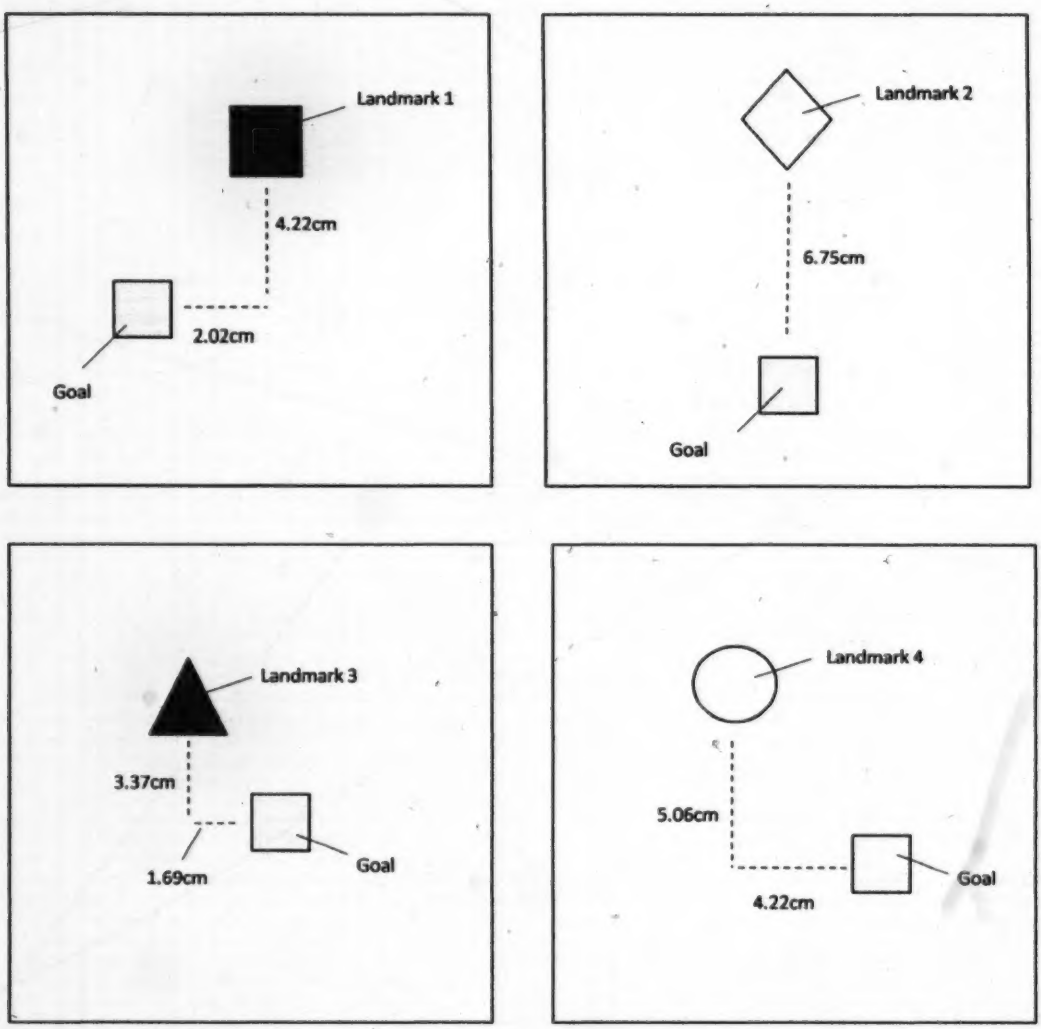

Figure 7. The location of the goal for each landmark in Experiment 4a. Images are not to scale.

Procedure. This experiment consisted of two training phases and a testing phase. Both training phases consisted of 16 trials, while the testing phase consisted of 48 trials.

In the initial training phase (henceforth referred to as "pre-training"), participants were presented with the landmark in a semi-random position on the screen

with its associated goal location. The positioning of the landmark was semi-random because it was limited in where it could appear so that neither the landmark or goal area would appear outside of the visible screen area. In this phase of the experiment, the goal was outlined in a black pen-line. Participants had 30 seconds and unlimited mouse clicks to click within the goal area. If they clicked within the goal area, they were rewarded with both a graphical reward and its associated sound clip. In the DO group the reward contingencies were contingent on landmark type, while in the NO group they were not. If participants did not select the goal within 30 seconds, they received the incorrect feedback as described in Experiment 3. Both correct and incorrect feedback were presented for two seconds. The second training phase (henceforth referred to as "training") was the same as the first training phase with the exception that the goal area was no longer outlined in black.

Testing was the same as training with the following exceptions. First, participants had one mouse-click to find the goal. If participants did not find the goal on the first mouse click, the trial was scored as incorrect and they received the incorrect feedback. Second, a tally screen was displayed for two seconds after each trial. This tally screen was the same as that used in testing for Experiment 3. After the tally screen disappeared, a two second ITI was initiated before the next trial began. At the end of the experiment, participants were shown a final tally screen detailing their performance in the task and were debriefed.

Results

Mean Error. Mean error was similar for both the DO and NO groups in training and testing. Two separate, independent samples t-tests were conducted: one on the mean error of the first choice (i.e., mouse click) in training, and one on the mean error in testing.

In training, mean error of participants' first mouse click in the DO group ($n = 20$) was .81, while in the NO group ($n = 20$) participants' had a mean error of .82. Levene's test for Equality of Variances was not significant $F(1, 38) = .40$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean error of participants' first choice, $t(38) = .10$, $p > .05$.

In testing, participants' mean error in the DO group was .45, while in the NO group participants had a mean error of .51. Levene's test for Equality of Variances was not significant $F(1, 38) = 1.50$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on participants' mean error, $t(38)$, .98, $p > .05$.

Mean Deviation from Goal. Mean deviation from the goal was similar for both the DO and NO groups in training and testing. All measurements in these analyses are the mean deviation in centimeters from the center of the goal area.

In training, the DO group had a mean deviation of 1.66cm from the goal on the first mouse click, while the NO group had a mean deviation of 1.26cm from the goal. Levene's test of Equality of Variance was not significant, $F(1, 38) = 1.90$, $p > .05$.

Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal for participants' first choice, $t(38) = 1.49$, $p > .05$.

In testing, the DO group had a mean deviation from goal of 1.11cm, while the NO group had a mean deviation from the goal of 1.19cm. Levene's test of Equality of Variance was not significant, $F(1, 38) = .12$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal, $t(38) = -.48$, $p > .05$.

Mean Number of Mouse Clicks to find the Goal. The number of mouse clicks participants made before they either found the goal or timed out in training was similar for both the DO and NO groups. In training, participants in the DO group required a mean of 17.05 mouse clicks to find the goal, while participants in the NO group required a mean of 16.84 clicks. Levene's test for Equality of Variances was not significant, $F(1, 38) = .63$, $p > .05$. Therefore, in the subsequent independent samples t-test, equal variances were assumed. The independent samples t-test revealed no significant effect of group on the number of mouse clicks required to find the goal, $t(38) = .05$, $p > .05$.

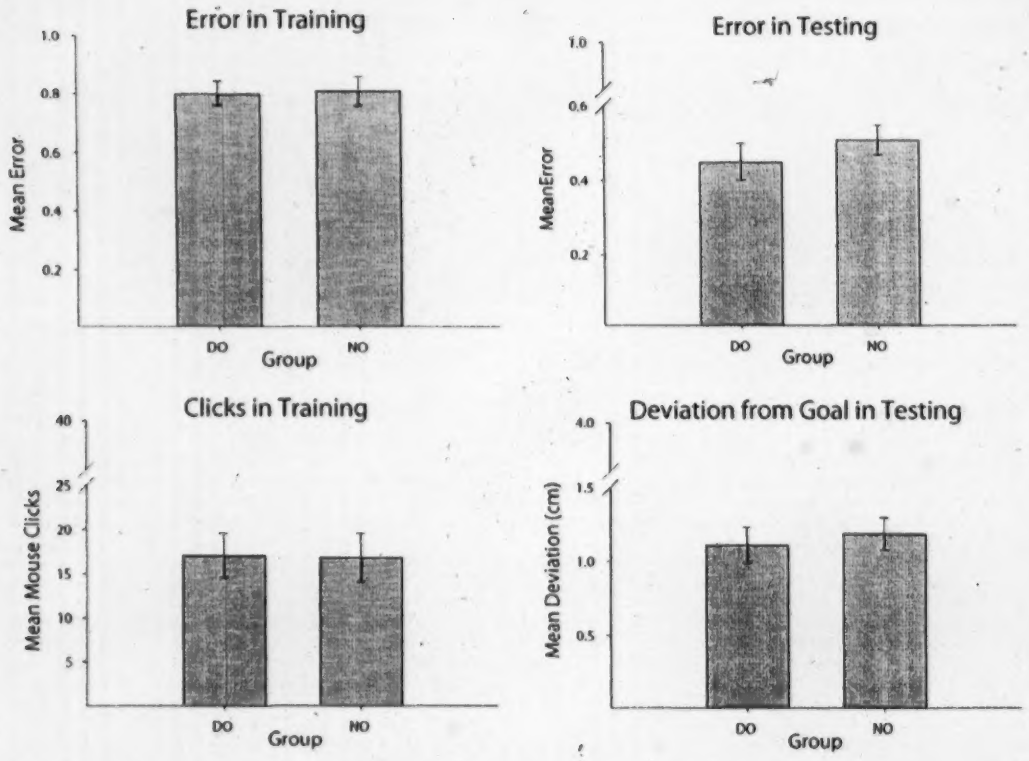

Figure 8. Graphical representations of proportional means and standard errors for the error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 4a. Error bars represent standard error of the mean.

Table 2

Summary of Results from Experiment 4a.

Measure	Phase of Program	t-statistic	Significant[a] ($p < .05$)?
Mean Error	Training	.10	No
	Testing	.98	No
Mean Deviation from the Goal	Training	1.49	No
	Testing	.48	No
Mean Number of Mouse Clicks	Training	.05	No

[a]All statistical tests were two-tailed tests.

Discussion

There was no evidence for the enhancement of search accuracy when using differential outcomes in this spatial localization task. It is possible that this was due to the low number of training trials participants received. It may be that participants in the DO group did not receive enough experience with the landmarks and their associated rewards to notice the relationship, and therefore performed as if they were in the NO group. I therefore replicated Experiment 4a but increased the number of training and testing trials to further test if a working memory component is required to enhance search accuracy when using differential outcomes in the spatial domain.

Experiment 4B

Although in Experiment 4a I did not see an enhancement of search accuracy when using differential outcomes, it may have been due to insufficient training. Relative to Experiment 3, in which participants had 80 training trials before testing, participants

in Experiment 4a had only 32. With so few training trials in Experiment 4a, it is possible that participants in the DO group were not able to learn the associations between the type of landmark presented and the particular reward associated with it. Thus, if participants did not learn the rewards associated with each landmark, they would be unable to form expectancies that could be used as additional discriminative cues. Without the formation of these unique expectancies, participants in the DO group would have performed similar to those in the NO group. Therefore, in this experiment I increased the number of training trials.

Method

Participants. Participants were 40 first year Psychology students (11 males, 29 females) aged 17 – 43 (M = 19.98, SD = 4.71) recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. The materials and apparatuses used in this experiment were the same as described in Experiment 4a.

Procedure. This experiment's procedure was the same as Experiment 4a with the following exception: the number of trials in each training phase was increased. There were 32 trials in pre-training and 48 trials in training and testing.

Results

Mean Error. Mean error was significantly lower for participants in the DO group than those in the NO group in training. However, mean error was similar for both the DO and NO groups in testing. Two separate analyses were conducted: one on the mean error of the first choice (i.e., mouse click) in training, and one on the mean error in testing.

In training, the DO group (n = 21) had a mean error of .55 on the first mouse click, while the NO group (n = 22) had a mean error of .72. Levene's test for Equality of Variances was not significant, $F(1, 41) = 1.22$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed a significant effect of group on the mean error of participants' first mouse click, $t(41) = 2.28$, $p < .05$.

In testing, the DO group had a mean error of .28, while the NO group had a mean error of .38. Levene's test for Equality of Variances was not significant $F(1, 41) = .12$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on mean error, $t(41)$, 1.74, $p > .05$.

Mean Deviation from Goal. The mean deviation of choices was similar in both the DO and NO groups. Two separate analyses were conducted: one on the mean deviation of the first choice (i.e., mouse click) from the goal in training, and one on the mean deviation from the goal in testing. All measurements in this analysis are the mean deviation in centimeters from the center of the goal area.

In training, the DO group had a mean deviation of .79cm from the goal for the first mouse click, while the NO group had a mean deviation of .87cm from the goal. Levene's test of Equality of Variances was not significant, $F(1, 41) = .03, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group for the mean deviation of the first mouse click from the goal, $t(41) = -.60, p > .05$.

In testing, the DO group had a mean deviation of .73cm from the goal, while the NO group had a mean deviation of .83cm from the goal. Levene's test of Equality of Variances was not significant, $F(1, 41) = .00, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal, $t(41) = -1.09, p > .05$.

Mean Number of Mouse Clicks to Find the Goal. The number of mouse clicks participants made before they either found the goal or timed out in training was similar for both the DO and NO groups. In the DO group the mean number of mouse clicks required to find the goal was 8.47, while the NO group required 13.41 clicks. Levene's test for Equality of Variances was not significant, $F(1, 41) = 3.14, p > .05$. Therefore, in the subsequent independent samples t-test, equal variances were assumed. The independent samples t-test revealed that there was no significant effect of group on the number of mouse clicks required to find the goal, $t(41) = 1.52, p > .05$.

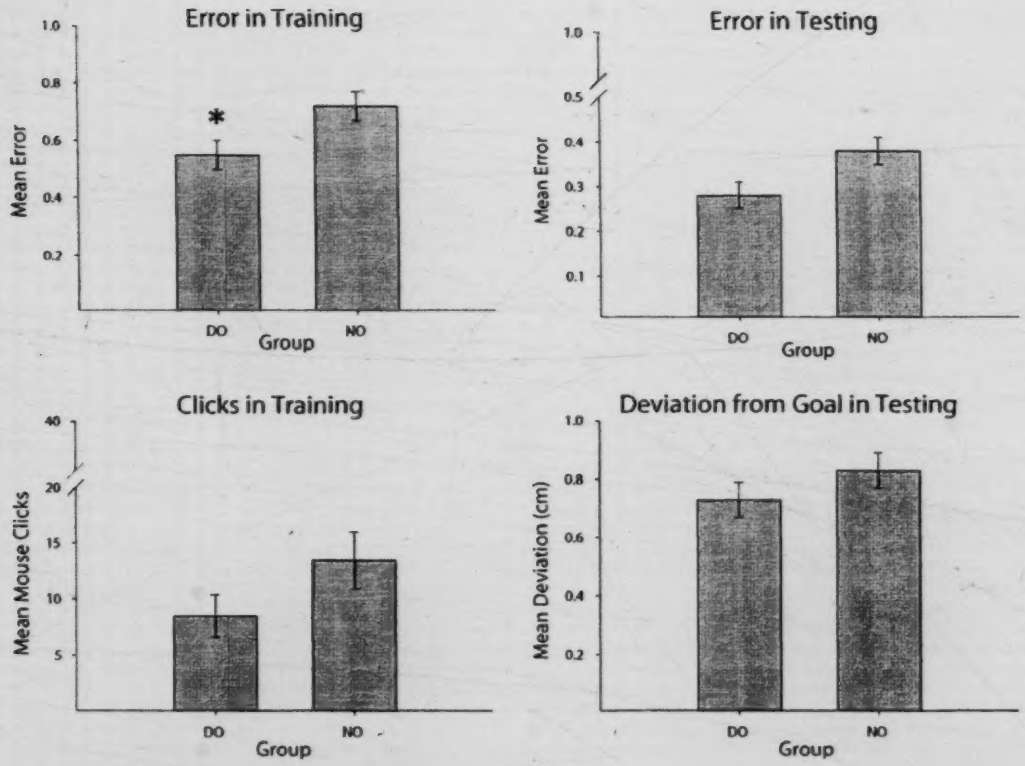

Figure 9. Graphical representations of proportional means and standard errors for error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 4b. Error bars represent standard error of the mean. An asterisk (*) above the DO bar indicates that the DO group differed significantly from the NO group in that statistical analysis ($p < .05$).

Table 3

Summary of Results from Experiment 4b.

Measure	Phase of Program	t-statistic	Significant[b] ($p < .05$)?
Mean Error	Training	2.28	Yes[a]
	Testing	1.74	No
Mean Deviation from the Goal	Training	-.60	No
	Testing	-1.09	No
Mean Number of Mouse Clicks	Training	-1.52	No

[a]DO group has significantly less (measure type) than the NO group.
[b]All statistical tests were two-tailed tests.

Discussion

A significant enhancement of search accuracy was observed in training when using DO in this experiment. However, this enhancement was not seen in testing. These findings suggest that when attempting to observe a significant DOE in adults in the spatial domain, having sufficient task difficulty is important.

The results of this experiment also support that notion that producing a DOE in the spatial domain is non-trivial. The results of this study, coupled with those of Experiments 1, 2 and 4a suggest that observing a significant DOE in the spatial domain is very difficult when the information to be remembered is spatial information. For example, I observed very large differences between groups in almost all measures in training and testing in Experiment 3, but only observed a single significant effect of group in one of the other four experiments (Experiment 4b). The difference between Experiment 3 and the other experiments presented thus far is that in Experiment 3, the

primary source of information to be remembered was object information (i.e., the particular primer object specified which goal location was active on a particular trial), while in the other four experiments the primary source of information to be remembered was spatial information.

While this idea is plausible, it is not the only explanation for the inability to observe a significant DOE in Experiments 1, 2, 4a and 4b. It is also possible that procedural differences between Experiment 3 and the other experiments are responsible for a significant DOE only being observed in Experiment 3. To determine if this was the case, I devised Experiments 5a and 5b.

Experiment 5a

To determine whether procedural differences or the primary type of information to be remembered (i.e., object vs. spatial information) between Experiment 3 and the other experiments discussed thus far (i.e., Experiments 1, 2, 4a and 4b) was responsible for only observing a strong DOE in Experiment 3, I devised Experiment 5a. In this experiment, I used a similar procedure to Experiment 3, but changed the primary source of information to be remembered from object information to spatial information.

Method

Participants. Participants were 30 first year Psychology students (11 males, 19 females) aged 18 – 22 (M = 18.77, SD = .94) recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two

participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. The apparatus and all materials were the same as those used in Experiment 3, with the exception that different primer images were used. In this experiment the primer images were exact replicas of the landmark and its associated goal location for the upcoming trial (for details as to the distance and direction that each goal location was away from the landmark, see Experiment 3 and Figure 5). Primer images were 8.43cm^2 and were presented in the center of the screen. The goal location that was presented in the primer image was highlighted in red and contained the word "Goal" (see Figure 10 for images of the primers used).

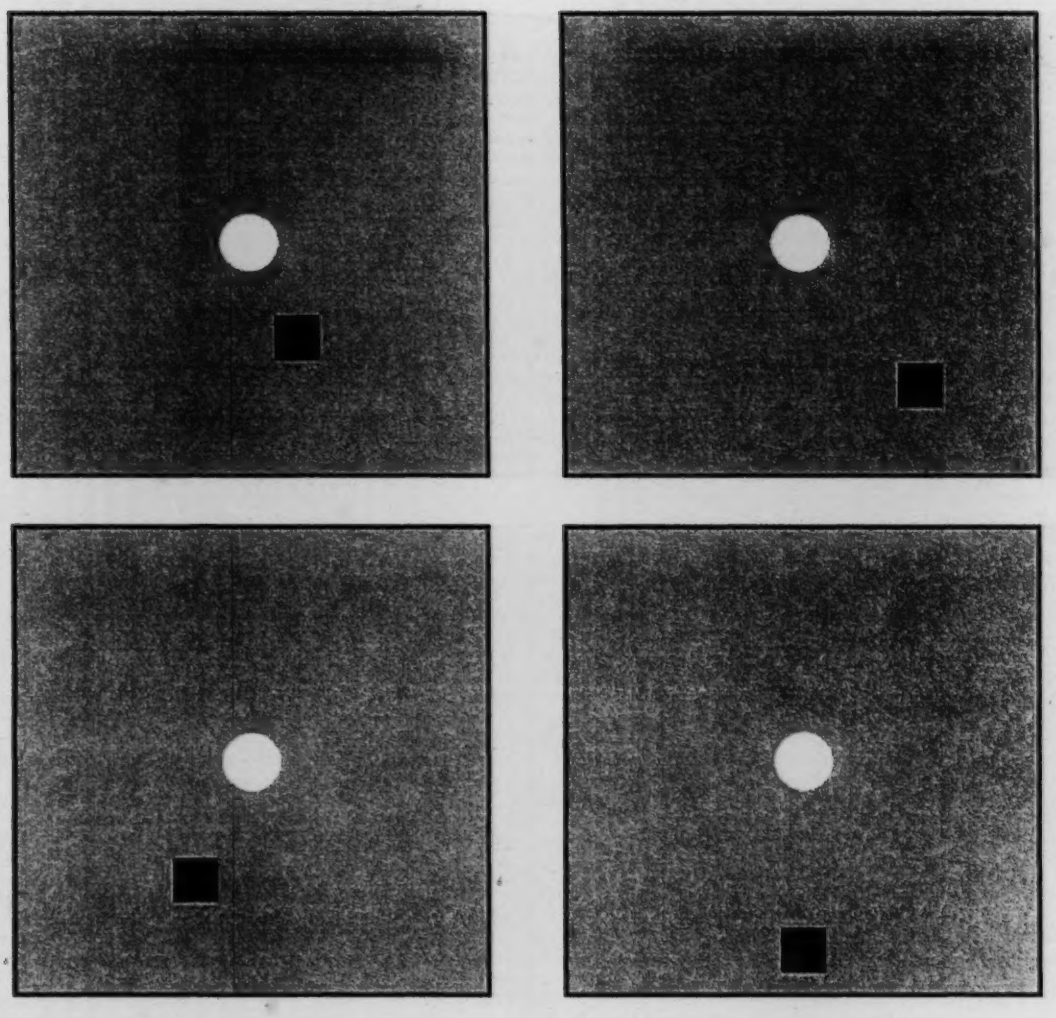

Figure 10. Primers used in Experiments 5a and 5b. Images are not to scale.

Procedure. The procedure for this experiment was the same as described in Experiment 3.

Results

Mean Error. Mean error was similar for both the DO and NO groups in training and testing. Two separate analyses were conducted: one on the mean error of the first choice (i.e., mouse click) in training, and one on participants' mean error in testing.

In training, the DO group (n = 15) had a mean error of .36 on the first choice, while the NO group (n = 15) had a mean error of .38. Levene's test for Equality of Variances was significant, $F(1, 28) = 4.47$, $p < .05$. Therefore, equal variances were not assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean error of participants' first choice, $t(20.69) = .47$, $p > .05$.

In testing, the DO group had a mean error of .24, while the NO group had a mean error of .21. Levene's test for Equality of Variances was not significant, $F(1, 28) = 2.28$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on mean error, $t(28) = -.76$, $p > .05$.

Mean Deviation from the Goal. Mean deviation from the goal was similar for the DO and NO groups, both in training and testing. All measurements in this analysis are the mean deviation in centimeters from the center of the goal area.

In training, the DO group had a mean deviation of .50cm from the goal on the first mouse click, while the NO group had a mean deviation of .48cm from the goal. Levene's test of Equality of Variance was not significant, $F(1, 28) = 2.06$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test.

The independent samples t-test revealed no significant effect of group on the mean deviation of participants' first mouse click from the goal, $t(28) = 1.09, p > .05$.

In testing, the DO group had a mean deviation of .64cm from the goal, while the NO group had a mean deviation of .61cm from the goal. Levene's test of Equality of Variance was not significant, $F(1, 28) = .33, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on participants' mean deviation from the goal, $t(28) = .66, p > .05$.

Mean Number of Mouse Clicks to Find the Goal. The number of mouse-clicks required to either find the goal or time out in training was similar for the DO and NO groups. The DO group required a mean of 2.18 mouse clicks to find the goal, while the NO group required a mean of 2.26 clicks. Levene's test for Equality of Variances was not significant, $F(1, 41) = .50, p > .05$. Therefore, in the subsequent independent samples t-test, equal variances were assumed. The independent samples t-test revealed that there was no significant effect of group on the number of mouse clicks required to find the goal, $t(28) = .72, p > .05$.

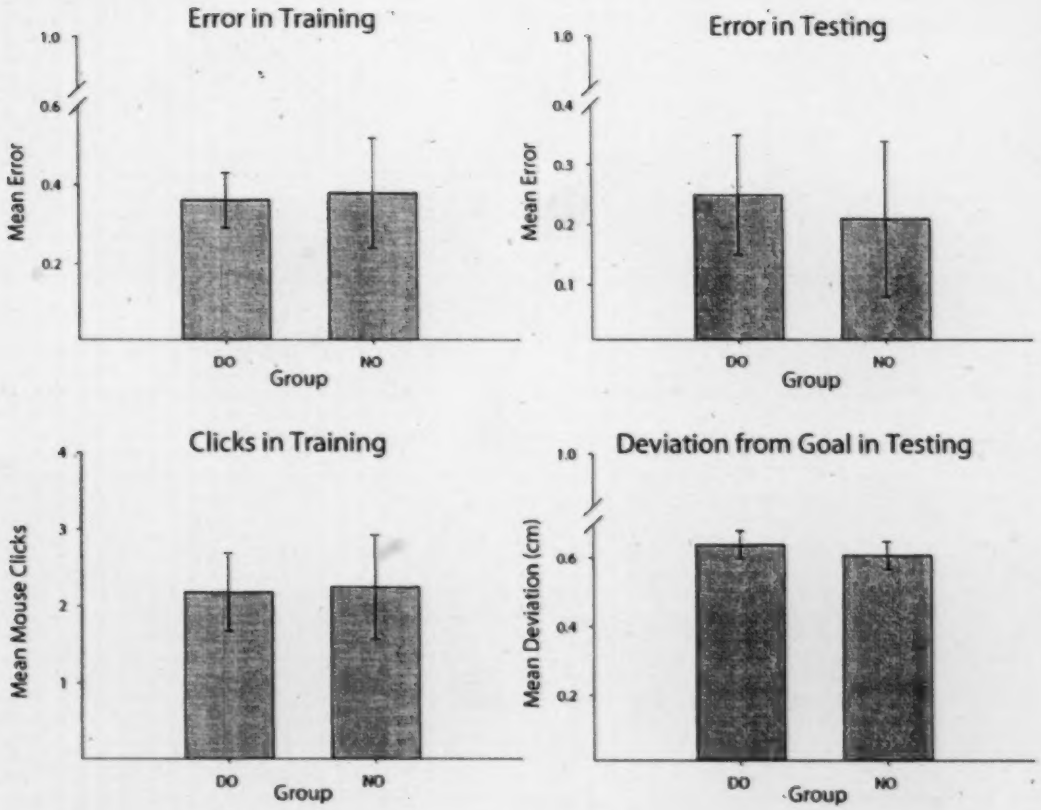

Figure 11. Graphical representations of proportional means and standard errors for the error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 5a. Error bars represent standard error of the mean.

Table 4

Summary of Results from Experiment 5a.

Measure	Phase of Program	t-statistic	Significant[a] ($p < .05$)?
Mean Error	Training	.47	No
	Testing	-.76	No
Mean Deviation from the Goal	Training	1.09	No
	Testing	.66	No
Mean Number of Mouse Clicks	Training	.72	No

[a]All statistical tests were two-tailed tests.

Discussion

Although I did not observe an enhancement of search accuracy in the DO group, it may have been because the task was not sufficiently difficult. Thus, it is possible that a DOE was obscured by the high levels of accuracy present in this experiment (i.e., a ceiling effect occurred). To counteract this potential problem, I created Experiment 5b in which I attempted to make the task more difficult.

Experiment 5b

While I did not see an enhancement of search accuracy in Experiment 5a, it may have been due to the task being relatively easy. Thus, in Experiment 5b I significantly increased the difficulty of the task to lower overall accuracy while still maintaining a spatial working memory component. To do this, I made three essential changes to Experiment 5a to test our hypothesis: primer image sizes were decreased, a retention interval was introduced, and a distracter task was implemented. I hypothesized

that these changes would significantly lower participants' overall accuracy throughout the experiment. Thus, by removing the potential for a ceiling effect, I expect to see an enhancement of search accuracy when using differential outcomes.

Method

Participants. Participants were 40 first year Psychology students (21 males, 19 females) aged 18 – 40 (M = 20.85, SD = 4.36) recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. The materials used in this experiment were the same as those used in Experiment 5a with the following exceptions. First, the primer images were scaled down by 50% (primers were now 4.22cm^2). Second, a distracter task replaced the RI between the presentation of the primer and the spatial localization task in testing. The distracter task, further described in the procedure section below, contained two different distracter images which participants had to click with the mouse. These images were a green equilateral triangle (sides = 1.64cm) in the center of a red square (sides = 2.02cm). The triangle was either normally positioned (i.e., 0° of rotation) or upside-down (i.e., rotated 180°). Feedback images were presented to participants after every distracter, indicating whether they were correct or incorrect. The correct feedback was an image of a green checkmark, while the incorrect feedback was

an image of a red "X". These reward images were 8.43cm^2 and were always presented in the center of the screen.

Procedure. The procedure of this experiment was the same as Experiment 5a with the following exceptions. First, a two second RI was placed between the disappearance of the primer and the presentation of the spatial localization task in training. Second, a distracter task was included between the disappearance of the primer and the presentation of the spatial localization task in testing. Participants had to click this image within the 2.5 seconds. Moreover they had to click on the image with the left mouse button if the triangle was presented at 0° and the right mouse button if the triangle was presented at 180°. If participants clicked the image with the correct mouse button, the trial ended immediately and participants received the correct feedback. If participants did not click the image within 2.5 seconds, or clicked the image with the incorrect mouse button, they received the incorrect feedback. The feedback images were displayed on the screen for 0.5 seconds, after which a new distracter trial would begin. Participants received six semi-random distracter images for each distracter task. The distracter images presented to participants were semi-random in that three of each type of distracter image were presented, but the order was random. After the final distracter task was completed and feedback given, the landmark (i.e., the white circle) appeared on the screen in the same manner as described in Experiment 5a.

Results

Mean Error. Mean error was similar for both the DO and NO groups in training and testing. Two separate analyses were conducted, one on the mean error of the first choice (i.e., mouse click) in training, and one on the mean error in testing.

In training, the DO group (n = 20) had a mean error of .47 on the first choice, while the NO group (n = 20) had a mean error of .56. Levene's test for Equality of Variances was significant, $F(1, 38) = 10.03$, $p < .05$. Therefore, equal variances were not assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean error of participants' first choice, $t(29.03) = 1.68$, $p > .05$.

In testing, the DO group had a mean error of .32, while the NO group had a mean error of .39. Levene's test for Equality of Variances was not significant, $F(1, 21) = .01$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on mean error, $t(38) = 1.54$, $p > .05$.

Mean Deviation from the Goal. Mean deviation from the goal was similar for the both the DO and NO groups in training and testing. All measurements in this analysis are the mean deviation from the center of the goal area in centimeters.

In training, the DO group had a mean deviation of .54cm from the goal on the first mouse click, while the NO group had a mean deviation of .59cm from the goal. Levene's test of Equality of Variances was not significant, $F(1, 38) = 1.64$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test.

The independent samples t-test revealed no significant effect of group on the mean deviation from the goal of participants' first choice, $t(38) = -1.16, p > .05$.

In testing, the DO group had a mean deviation of .85cm from the goal, while the NO group the mean deviation .93cm from the goal. Levene's test of Equality of Variances was not significant, $F(1, 38) = .15, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal, $t(38) = -.95, p > .05$.

Mean Number of Mouse Clicks to Find the Goal. The mean number of mouse clicks participants made before they found the goal or timed out in training was similar for both the DO and NO groups. The DO group required a mean of 3.37 mouse clicks to find the goal, while the NO group required a mean of 4.13 clicks to find the goal. Levene's test for Equality of Variances was significant, $F(1, 38) = 7.30, p < .05$. Therefore, in the subsequent independent samples t-test, equal variances were not assumed. The independent samples t-test revealed no significant effect of group on the number of mouse clicks required to find the goal, $t(30.11) = -1.43, p > .05$.

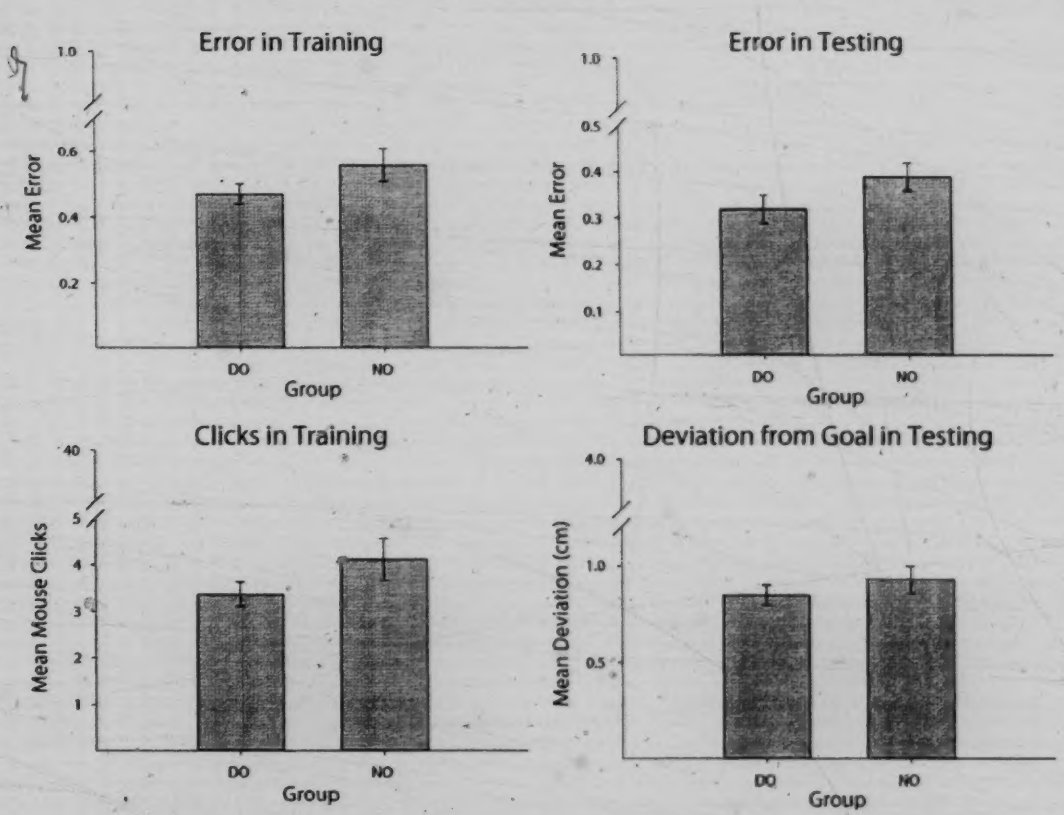

Figure 12. Graphical representations of proportional means and standard errors for the error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 5b. Error bars represent standard error of the mean.

Table 5

Summary of Results from Experiment 5b.

Measure	Phase of Program	t-statistic	Significant[a] ($p < .05$)?
Mean Error	Training	1.68	No
	Testing	1.54	No
Mean Deviation from the Goal	Training	-1.16	No
	Testing	-.95	No
Mean Number of Mouse Clicks	Training	-1.43	No

[a]All statistical tests were two-tailed tests.

Discussion

Although I used a procedure similar to that of Experiment 3 in both Experiments 5a and 5b, I did not see a significant enhancement of search accuracy when using DO in the spatial domain. Thus, these results support my hypothesis that when the information to be remembered is spatial information, producing a significant DOE is extremely difficult.

Experiment 6a

To investigate whether the difficulty of enhancing search accuracy when using DO is a product of the types of spatial localization tasks I have used thus far, I created a different type of spatial search task: namely a variant of the Huttenlocher task (Huttenlocher Hedges, & Duncan, 1991; see also Sandberg, Huttenlocher, & Newcombe, 1996). This spatial task is different from the spatial localization tasks I

have conducted thus far and has both a spatial working memory component and a high level of difficulty. It may be that this different type of spatial localization task will be more sensitive to differences in search accuracy between the DO and NO groups. If this is the case, then I should see a significant DOE in this experiment.

Method

Participants. Participants were 50 first year Psychology students recruited from the University of Alberta's research participation pool. The age and sex of the first 29 participants were not recorded due to a software problem. The remaining 21 participants consisted of 7 males and 14 females and had an age range of 18 – 25 years (M = 19.05, SD = 1.66). Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. Participants were tested in the same room and with the same computer equipment that was used in Experiment 3. Reward images and sound clips were also the same as those used in Experiment 3.

Stimuli consisted of a large, transparent circle (diameter = 20.58cm) outlined by a thin yellow pen-line (henceforth referred to as the "boundary circle") and a smaller, opaque red goal circle (diameter = 2.02cm) (henceforth referred to as the "goal circle") which appeared within the boundary circle. In the first phase of training, lines segmenting the four quadrants of the boundary circle were visible. These quadrant lines

were of the same color and style as the lines denoting the outside circumference of the boundary circle. In the second phase of training, these quadrant lines were no longer visible (see Figure 13 for a diagram).

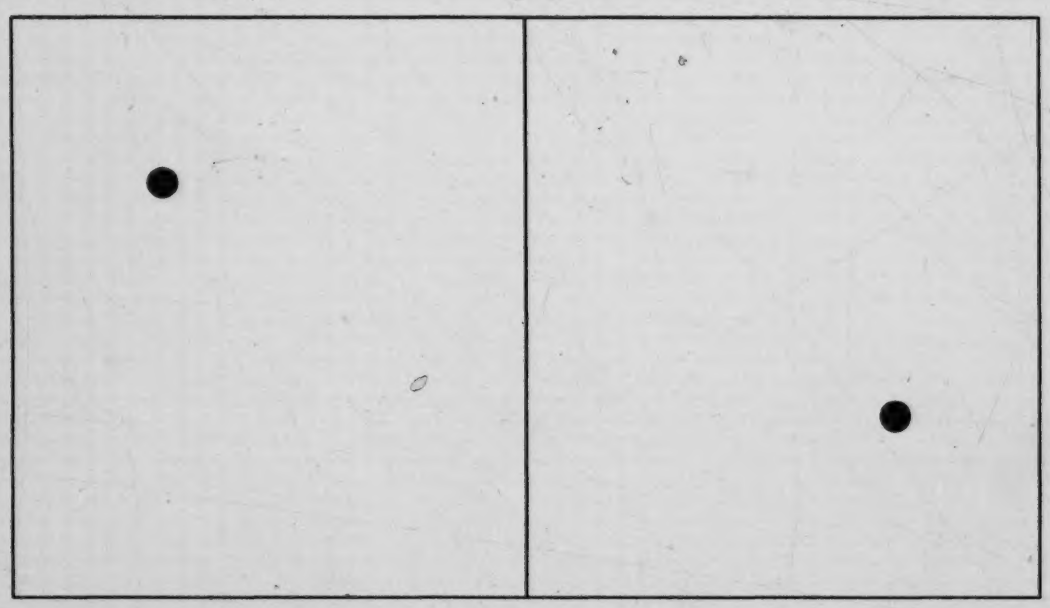

Figure 13. (*left*) The boundary (yellow) and goal (red) circles as they were presented in the first phase of training. *(right)* The boundary (yellow) and goal (red) circles as they were presented in the second phase of training and testing. Images are not to scale.

Procedure. There were two training phases and one testing phase in this experiment. In the DO group, the type of reward received was contingent upon which quadrant in the boundary circle the goal was located. (e.g., the top-left quadrant would always earn reward A; the top-right quadrant would always earn reward B, etc.). In the NO group, rewards were uncorrelated with which quadrant in the boundary circle the goal was located (e.g., if the goal was located in the top-left quadrant of the boundary

circle, participants had a 25% chance of the reward being reward A, B, C, or D). All feedback stimuli used in this experiment were the same as those used and described in Experiment 3.

The first phase of training consisted of 16 trials in which the boundary circle appeared in a semi-random screen location with the goal circle appearing semi-randomly within one of the quadrants of the boundary circle. The appearance of the boundary circle was semi-random such that no part of it could appear outside of the visible screen area. The location of the goal circle within the boundary circle was semi-random in that it could only appear in each quadrant on 25% of the trials. Furthermore, inside the boundary circle, the goal could not appear too close to edges of a quadrant (see Figure 15 for a diagram and specific details). In this phase of the experiment, participants were required to move the mouse and click on the goal circle to earn a reward. This phase was implemented to ensure participants realized that they should be searching for the goal circle, as well as to give participants in the DO group experience with the unique reward contingencies associated with each quadrant of the boundary circle.

The second phase of training consisted of 32 trials. Initially, the boundary and goal circles were displayed on the screen as described in the first phase of training. However, the boundary and goal circles were now presented for only two seconds, during which participants could not move the mouse. After the presentation time had elapsed, the screen was cleared and a two second RI ensued. When the RI ended, the boundary circle was once again displayed on the screen. However, it was presented in a different location on the screen then it had been originally. When the boundary circle

reappeared, the goal circle was not displayed with it. At this time, participants were given the ability to move the mouse again and had to locate the now invisible goal circle by clicking on it with the mouse. In this phase of training, participants had 30 seconds and unlimited mouse clicks to find the goal. If they did not locate the goal within 30 seconds, the trial was scored as incorrect and participants received the incorrect feedback (as described in Experiment 3). If participants located the goal within the 30 second time limit, the reward image was displayed where the goal was located and participants were presented with the sound clip that was associated with the graphical image they received. Rewards were presented for two seconds before the screen was cleared. There was then a one second ITI before the next trial began.

Testing was similar to the second phase of training with the following exceptions. First, a two second RI was placed between the initial presentation of the boundary and goal circles and the second presentation of the boundary circle. Second, when participants received feedback a thin red pen-line was drawn on top of the reward image to denote where the goal area was located. This was done because the reward images were larger than the goal and I did not want participants becoming confused if they clicked at the edge of a reward image but received the incorrect feedback. Third, a small opaque black dot was drawn on the screen where the participants clicked to further alleviate confusion during the presentation of feedback. Fourth and finally, after participants received feedback, a tally screen was presented which detailed how many of each reward participants had earned throughout the experiment. This tally screen was the same as that described in Experiment 3. The tally screen was provided for two seconds followed by a one second ITI between trials. After testing, participants were

provided with a final tally screen showing them their overall performance on the task and were debriefed (see Figure 14 for a diagram illustrating the procedure of a test trial).

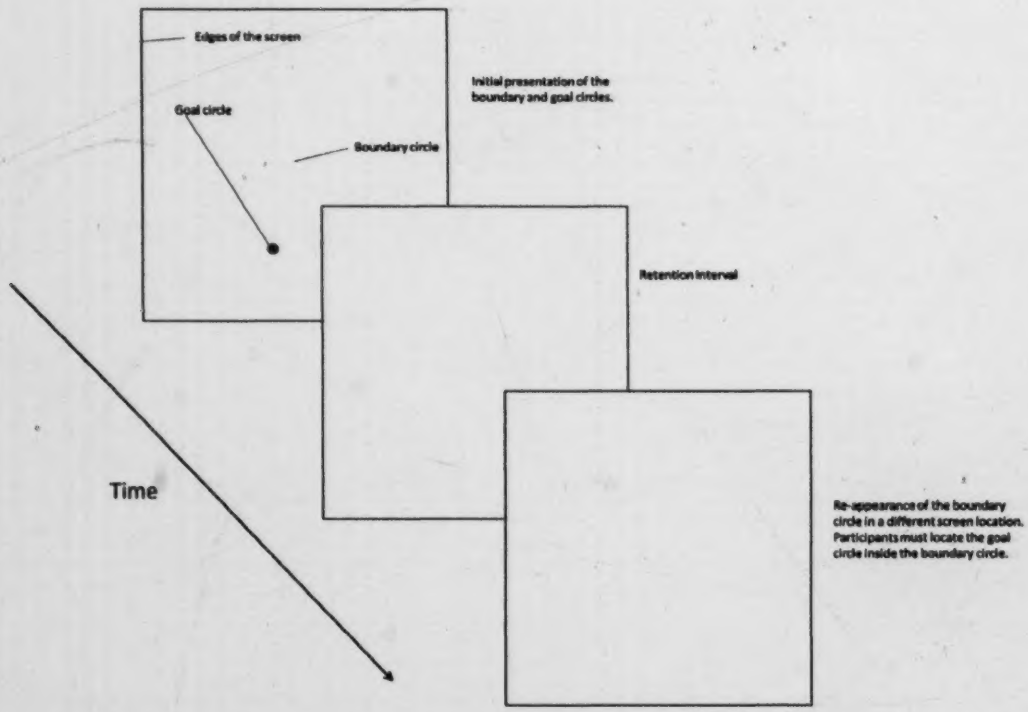
Edges of the screen
Initial presentation of the boundary and goal circles.
Goal circle
Boundary circle
Retention Interval
Time
Re-appearance of the boundary circle in a different screen location. Participants must locate the goal circle inside the boundary circle.

Figure 14. A diagram illustrating the procedure of a testing trial in Experiment 6a.

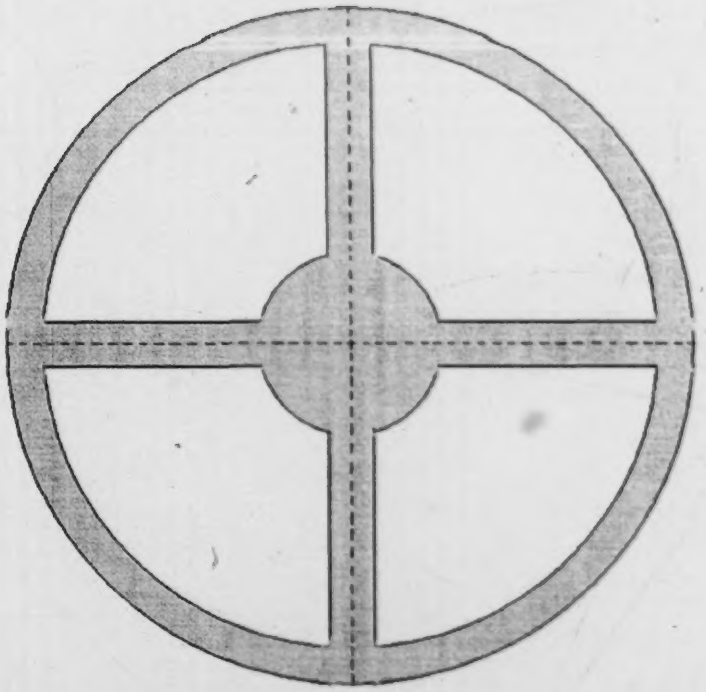

Figure 15. Diagram of the possible locations where the goal circle could appear (white areas) within the boundary circle for Experiments 6a and 6b. The shaded areas indicate areas in which the goal circle could not appear. Dashed lines indicate the quadrant lines of the boundary circle.

Results

Mean Error. Mean error in both training and testing, was similar for both the DO and NO groups. Two separate analyses were conducted: one on the mean error of the first choice (i.e., mouse click) in training, and one on the mean error in testing.

In training, the DO group (n = 30) had a mean error of .78 on the first choice, while the NO group (n = 20) had a mean error of .80. Levene's test for Equality of Variances was not significant, $F(1, 48) = .15$, $p > .05$. Therefore, equal variances were

assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean error of participants' first choice, $t(48) = .83, p > .05$.

In testing, the DO group had a mean error of .67, while the NO group had a mean error of .71. Levene's test for Equality of Variances was not significant, $F(1, 48) = .51, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on mean error, $t(48) = 1.08, p > .05$.

Mean Deviation from the Goal. Mean deviation from the goal was similar for both the DO and NO groups in training and testing. All measurements in this analysis are the mean deviation from the center of the goal in centimeters.

In the second phase of training, the DO group had a mean deviation of .64cm from the goal on participants' first choice, while the NO group had a mean deviation of .72cm from the goal. Levene's test of Equality of Variances was not significant, $F(1, 48) = 1.52, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal on participants' first choice, $t(48) = -1.25, p > .05$.

In testing, the DO group had a mean deviation of .91cm from the goal, while the NO group had a mean deviation of .99cm from the goal. Levene's test of Equality of Variances was significant, $F(1, 48) = 4.14, p < .05$. Therefore, equal variances were not

assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal, $t(24.67) = -.68, p > .05$.

Mean Number of Mouse Clicks to Find the Goal. The number of mouse clicks participants made before they either found the goal or timed out in the second phase of training was similar for the two groups. The DO group required a mean of 13.02 mouse clicks to find the goal, while the NO group required a mean of 13.09 clicks. Levene's test for Equality of Variances was not significant, $F(1, 48) = .13, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the number of mouse clicks required to find the goal, $t(48) = -.03, p > .05$.

Table 6

Summary of Results from Experiment 6a.

Measure	Phase of Program	t-statistic	Significant[a] (p < .05)?
Mean Error	Training	.83	No
	Testing	1.08	No
Mean Deviation from the Goal	Training	-1.25	No
	Testing	.68	No
Mean Number of Mouse Clicks	Training	-.03	No

[a]All statistical tests were two-tailed tests.

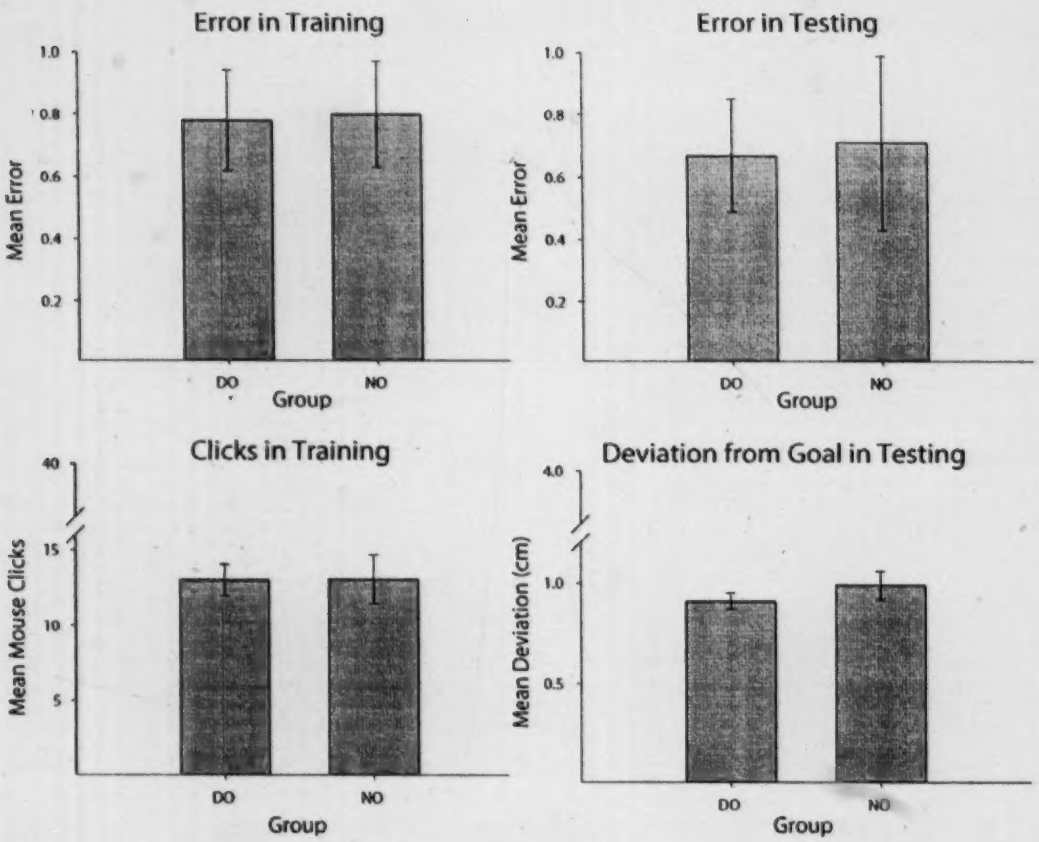

Figure 16. Graphical representations of proportional means and standard errors for error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 6a. Error bars represent standard error of the mean.

Discussion

In this experiment, I did not see an enhancement of search accuracy when using differential outcomes. However, accuracy in both training and testing were very low and this may have prevented the occurrence of a significant DOE. I suggest two

possible reasons for this. First, it is possible that participants in the DO group did not receive enough positive feedback to enable them to associate the different quadrants of the boundary circle with their different reward contingencies. Thus, if this was the case it would be expected that they would perform similar to participants in the NO group because they would be unable to form unique expectancies of the rewards associated with each quadrant. A second possibility is that a DOE may have been produced but it was so weak that it was obscured by the low levels of accuracy in this experiment; namely a floor effect may have occurred. To determine if it was one of these two reasons why I did not see an enhancement of search accuracy when using differential outcomes in this experiment, I devised Experiment 6b in which I significantly reduced the difficulty of the task.

Experiment 6b

While I did not observe an enhancement of search accuracy when using differential outcomes in Experiment 6a, this may have been due to the task being too difficult. I therefore devised Experiment 6b in which I doubled the size of the goal circle to make the task easier. This adjustment should allow participants to receive more positive feedback by making the task easier and allowing them to get more trials correct. Receiving more positive feedback should enable participants in the DO group to more readily associate the different quadrants with their associated reward contingencies. With these changes, I hypothesize that I should see an enhancement of search accuracy when using differential outcomes.

Method

Participants. Participants were 20 first year Psychology students (7 males, 13 females) aged 17 – 28 (M = 19.4, SD = 2.5) recruited from the University of Alberta's research participation pool. Participants received partial course credit for participating in the experiment. All participants had normal or corrected-to-normal vision. Two participants were tested in the same room at the same time, each back-to-back at desks facing different walls.

Materials & Apparatus. All materials and apparatuses were the same as those used and described in Experiment 6a with the following exception: the size of the goal circle was doubled (diameter = 4.04cm).

Procedure. The procedure was the same as described in Experiment 6a.

Results

Mean Error. Mean error was similar for both the DO and NO groups. Two separate analyses were conducted, one on the mean error of participants first choice (i.e., mouse click) in the second phase of training, and one on participants mean error in testing.

In the second phase of training, the DO group (n = 10) had a mean error of .47cm on the first choice, while the NO group (n = 10) had a mean error of .57. Levene's test for Equality of Variances was not significant, $F(1, 18) = .00$, $p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test.

The independent samples t-test revealed no significant effect of group on the mean error of participants' first choice, $t(18) = 1.98, p > .05$.

In testing, the DO group had a mean error of .47, while the NO group had a mean error of .43. Levene's test for Equality of Variances was not significant, $F(1, 18) = .10, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on mean error, $t(48) = -.53, p > .05$.

Mean Deviation from the Goal. Mean deviation from the goal was similar for both the DO and NO groups in the second phase of training and testing. All measurements in these analyses are the mean deviation from the center of the goal area in centimeters.

In training, the DO group had a mean deviation of .71cm from the goal on participants first choice, while the NO group had a mean deviation of .76cm from the goal. Levene's test of Equality of Variance was not significant, $F(1, 18) = 1.07, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation of participants' first choice from the goal, $t(18) = -.65, p > .05$.

In testing, the DO group had a mean deviation of 1.09cm from the goal, while the NO group had a mean deviation of 1.01cm from the goal. Levene's test of Equality of Variances was not significant, $F(1, 18) = 1.77, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the mean deviation from the goal, $t(18) = .88, p > .05$.

Mean Number of Mouse Clicks to Find the Goal. The number of mouse clicks participants made before they either found the goal or timed out in training was similar for both the DO and NO groups. The DO group required a mean of 5.25 mouse clicks to find the goal, while the NO group required a mean of 5.70 mouse clicks to find the goal. Levene's test for Equality of Variances was not significant, $F(1, 18) = .21, p > .05$. Therefore, equal variances were assumed in the subsequent independent samples t-test. The independent samples t-test revealed no significant effect of group on the number of mouse clicks required to find the goal, $t(18) = -.30, p > .05$.

Table 7

Summary of Results from Experiment 6b.

Measure	Phase of Program	t-statistic	Significant[a] ($p < .05$)?
Mean Error	Training	1.98	No
	Testing	-.53	No
Mean Deviation from the Goal	Training	-.65	No
	Testing	.88	No
Mean Number of Mouse Clicks	Training	-.30	No

[a]All statistical tests were two-tailed tests.

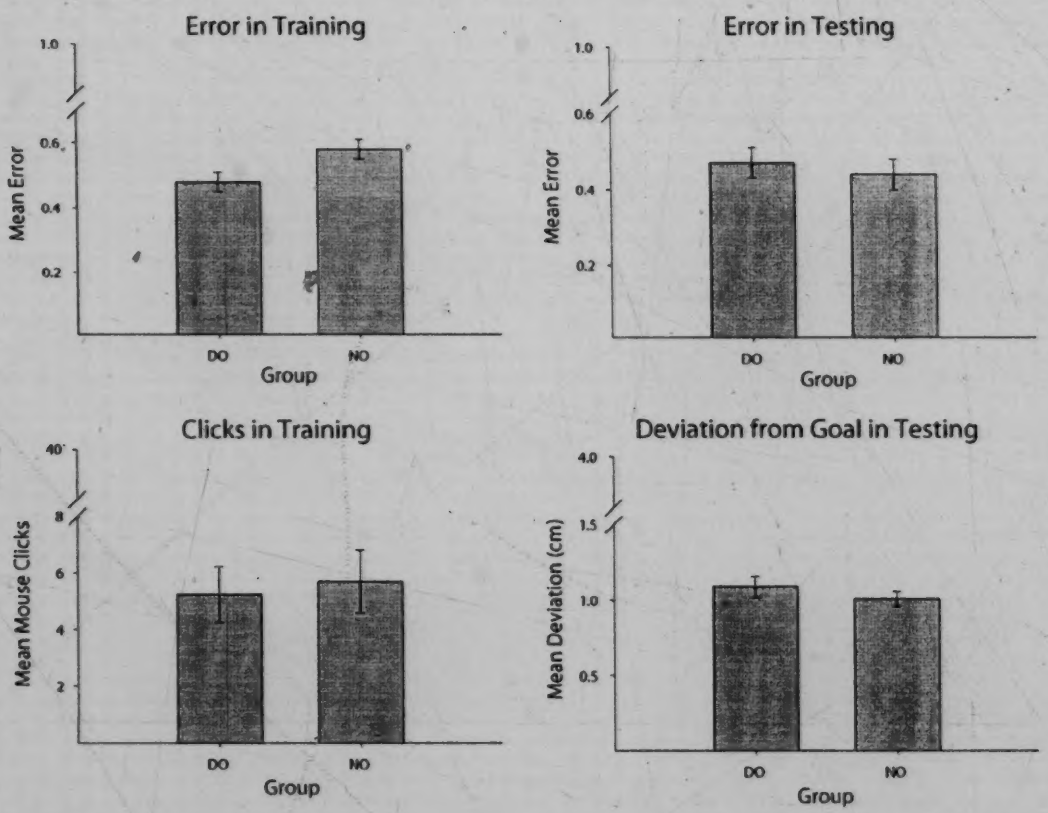

Figure 17. Graphical representations of proportional means and standard errors for error in training (*top left*), error in testing (*top right*), number of mouse clicks required to find the goal (*bottom left*) and deviation from the goal in testing (*bottom right*) in both the DO (*dark gray bars*) and NO (*light gray bars*) groups in Experiment 6b. Error bars represent standard error of the mean.

Discussion

In this experiment, I did not see an enhancement of search accuracy when using differential outcomes. One possible reason for this is that participants in the DO group may not have readily associated the different quadrants of the boundary circle with the unique reward contingencies associated with each quadrant. If this was the case, they

would have performed similar to the NO group because they would be unable to use the distinct reward expectancies as another discriminative cue. The results of this experiment and Experiment 6a suggest that the Huttenlocher task was not more sensitive to differences in search accuracy when using DO relative to NO. Furthermore, because I did not observe a significant enhancement of search accuracy in this task, it adds further support to the theory that when the primary source of information to be remembered is spatial information, producing a DOE is very difficult and can only occur under very specific circumstances (e.g., a very difficult task). Clearly, our results show that, when using differential outcomes in the spatial domain, sufficient task difficulty and an explicit working memory component are not the only requirements for enhancing search accuracy.

General Discussion

The experiments presented in this paper demonstrate that it is possible to enhance search accuracy when using differential outcomes in the spatial domain (see Experiment 3 and Experiment 4b). To my knowledge, this is the first evidence of a significant DOE being produced in a spatial task without fixed, discrete choices such as in a matching-to-position task (Ramos & Savage, 2003; Savage et al., 1999). However, I have found that it is not easy to enhance search accuracy when using differential outcomes in spatial tasks. Instead, it seems that an enhancement of search accuracy when using differential outcomes in the spatial domain can only be made under very specific and constrained conditions.

One possible reason I only infrequently observed a DOE in spatial search tasks is that spatial memory may already be a privileged type of memory and cannot easily be further enhanced. Evidence for this comes from studies of mnemonic strategies. Specifically, mnemonic strategies which use a spatial component, such as the Method of Loci, have been shown to be more effective than mnemonic strategies that do not contain a spatial component (Rodiger, 1980; for a description of the Method of Loci and historical use, see Yates, 1966). That is, transforming item information into a spatial code appears to enhance people's memory for information over a delay, in much the same way that transferring item information into a reward code enhances sample memory in delayed matching to sample tasks. This theory is supported by our data, in which a strong DOE was only produced when I used abstract non-spatial primers. When abstract primers were used, the task required people to remember specific item information (e.g., the type of primer) in order to determine where to search. In this case, providing differential rewards facilitated performance. When the task was changed to rely more heavily upon spatial memory, I only observed a significant enhancement of search accuracy using differential outcomes in one measure of one experiment (mean error in training in Experiment 4b). Although my data almost always indicated a trend towards an enhancement of search accuracy when using differential outcomes, the difference between the DO and NO groups almost always did not reach significance. It is possible that if spatial memory is already an enhanced type of memory, then tasks which rely heavily upon spatial memory may be less susceptible to further enhancement by differential outcomes.

These possibilities, while intriguing, need to be studied further. One important future direction of study would be to test different mnemonic strategies using a differential outcomes procedure. Specifically, differential outcomes might enhance recall of items when using non-spatial mnemonic strategies (e.g., rehearsal, mental image method) but not when using mnemonics that rely heavily upon spatial memory (e.g., Method of Loci). If this turns out to be true, then it would add strong support for the theory that spatial memory is a special type of associative memory.

In conclusion, I have demonstrated the first evidence of a significant DOE in the spatial domain. However, this finding is not as clear as I would like, as it seems that enhancing search accuracy by using differential outcomes in the spatial domain is not an easy or versatile phenomenon. Although it is not entirely clear why it is so difficult to enhance search accuracy when using differential outcomes in the spatial domain, it may be because spatial memory is already a privileged type of associative memory that enhances recall. If this is true, then under most circumstances, the use of differential outcomes may not be able to further enhance search accuracy enough to produce significant differences between participants. Future research is required to determine if our theory is correct in explaining why enhancing search accuracy by using differential outcomes in the spatial domain is so difficult, and if a DOE can be produced in other spatial memory tasks.

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Appendix A

Appendix Table 1

Summary of Results for all Experiments

Experiment	Task Description	Findings	Reasoning / Comments
Experiment 1	Two landmark, two goal spatial localization task. Rewards were arbitrary graphical images.	No significant difference between DO and NO groups.	Rewards were not salient enough for different expectancy formations.
Experiment 2	Similar to Experiment 1 but rewards were graphical images of Canadian Coins. Participants received the money that they earned..	No significant difference between DO and NO groups. However, results indicated a trend towards a significant DOE.	Task may need to be more difficult and/or contain a strong working memory component to observe a significant DOE.
Experiment 3	Working memory task with a common landmark. Active goal locations indicated by object primers. Rewards were graphical images of items university students commonly misplace and associated sound clips.	Observed a significant DOE in mean error in training, mean error in testing, mean number of mouse clicks required to find the goal in training, and mean deviation from the goal in testing.	First observed DOE in the spatial domain. Why was a DOE observed in this Experiment but not Experiments 1 and 2?
Experiments 4a and 4b	Four landmark, four goal spatial localization task. Rewards were the same as Experiment 3. Experiment 4a had significantly reduced number of training trials, while Experiment 4b had the same number of training trials as Experiment 3.	No significant DOE observed in Experiment 4a. Significant DOE observed for the mean error in training in Experiment 4b. Other measures suggest a trend towards a DOE.	Experiments demonstrate producing a DOE in the spatial domain is very difficult. The reason why is unclear. One hypothesis is that when the primary source of information to be remembered is spatial, a DOE is very difficult to produce.
Experiments 5a and 5b	Similar to Experiment 3 but with spatial primers instead of object primers. Experiment 5b had a distracter task included in testing to make the task more difficult.	No significant DOE observed in Experiment 5a. No significant DOE observed in Experiment 5b, however the results suggest a trend towards a DOE.	Results add further support to the idea that producing a DOE is difficult when the information to be remembered is spatial.
Experiments 6a and 6b	Developed a different type of spatial localization task to see if a different type of test would be more sensitive when measuring differences between DO and NO groups: namely a variant of the Huttenlocher task.	No significant DOE observed in either Experiment 6a or 6b.	Test was not more sensitive than other spatial localization tasks conducted.

Appendix B

Example of Verbal Instructions given to Participants

An example of verbal instructions read to participants before starting an experiment. These particular instructions were used for Experiments 4a and 4b. Bolded text is used as a signal for the experimenter to perform a particular action. The action to be preformed is written in the bolded text.

First and foremost, I would like to thank you for coming. Without your participation in experiments like this it would be extremely difficult to conduct research.

Before I do anything, I would like you to read and sign this consent form ***hand them consent form***. With science, as with many other things, no one is going to force you to participate. That would just be unfair. I know you have to come here to obtain your 2% credit, but the department will not make you participate in an experiment if you don't want to. That is why I have an alternative task that you can do instead of the experiment. Unfortunately, I can't tell you about the experimental task unless you agree to do it because of experimental control reasons. However, I can let you know what the alternative task will be... With the alternative task, you will have to read an article and answer a series of questions on it. You will answer the questions with a pen and paper and will not require the use of the computer. So, before I go any further, I will need you to let me know what you would like to do.

****after accepting the computer task****

Now that you have decided to do the experiment, I will now read you a few rules and then you can begin the experiment. Instructions informing you of what you should do in this task will appear on the computer screen from time to time. So, now on to the rules.

Here begins the standardized set of instructions

The rules of the experiment are as follows:

First, do not use your hands or anything as measurement devices. This is considered cheating and you will lose participation credit for this exercise. Second, do not talk to the people around you. This is an individual task and must be treated as such. Third, if you have a cell phone please turn it off for the duration of the experiment. Finally, if you finish before the other person, please make every effort to leave quietly. I will give you your debriefing form which will tell you everything you need to know about the experiment to read at your leisure and then you can go.

The information regarding each task that you will experience in this experiment will be displayed on the computer screen before each stage of the experiment. However, one thing that I do ask is that you read these instruction screens fully. Some of these screens may contain extra information that may help you in the upcoming task. If you don't

read the instruction screen it is highly likely that you will find the following task extremely difficult and frustrating.

So that's everything… any questions?

Appendix C

Example of Instructions Presented within a Program

An example of instructions presented to participants on the computer screen during an experiment. These particular instructions were used for Experiment 3.

Before beginning the experiment:

Welcome. Thank you for participating in this experiment!

Please click anywhere on the screen to move to the instructions.

You are now entering Stage 1 of the experiment.

In this experiment your task will be to locate and click a goal. This goal, although visible initially, will be hidden later in the experiment. To begin, the goal area will be highlighted with a black outline.

The white circle is a landmark that will continue to appear throughout the experiment.

Please pay close attention to the image that appears in the top left

corner of the screen, the white circle, and the goal area. These images will be VERY important later in the experiment. Without knowledge from these initial stages of the experiment you will find the later stages of the experiment quite lengthy, frustrating, and difficult. Good luck!

After the first pre-training phase but before the second pre-training phase:

You are now entering Stage 2 of the Experiment.

The image that was previously displayed in the top left corner of the screen will now be displayed prior to a delay.

After the delay only the white circle and the goal will be shown.

Your task is to click the goal location with the mouse.

This will be the last time that the goal area is visible (i.e. outlined in black).

Good Luck!

After the second pre-trainjng phase but before training:

You are now entering Stage 3 of the experiment.

his stage will begin to test what you have learned thus far.

Your task is to find the goal location in as few mouse clicks and in the shortest amount of time possible.

Although this stage is similar to Stage 2 (the one you just finished), it is important to note that the goal area will no longer be visible.

Please click the left mouse button to start Stage 3. Good Luck!

After training but before testing:

You are now entering the final stage of the experiment.

The goal is once again hidden.

This stage will be very similar to the previous stage (Stage 3). The only difference is that in this stage you will have only **one** mouse click to find the goal.

You will earn rewards for finding the goal. You will receive incorrect for not finding it on a given trial (i.e. not finding the goal on the first click).

A record will be kept of your performance and the amount of each graphical reward you have earned. Both accuracy and reaction time will also be recorded.

Your task is to be as accurate and as fast as possible. Good luck!

After testing (end of the experiment):

You are now finished with the experiment.

Please signal to the experimenter that you are finished to receive your debriefing.

If another person is still working on the experiment, either wait quietly for them to finish or quietly obtain your debriefing form from the experimenter and leave as quietly as possible.

Thank you for your participation!

Really, THANKS!

Appendix D

Consent Form Example

A copy of a consent form participants would have to read and sign before beginning an experiment. This particular consent form was used for Experiments 4a, 4b, 5a, 5b, 6a, and 6b. Personal information such as names, email addresses, and phone numbers have been removed for privacy reasons.

Research Information and Participants' Consent Form:

Purpose. You are invited to participate in a research study (Study: Pelk 314) being conducted by Eric Legge of the Department of Psychology, University of Alberta. This study examines students' performance on a spatial memory and localization task. I are interested in how accurate students perform in the current task.

Your participation. Your participation involves searching for hidden rewards in a computerized spatial environment. It will take approximately 30-40 minutes to complete this task. You will receive your 2% credit for your participation.

Your rights. Your decision to participate in this study is entirely voluntary and you may decide at any time to withdraw. If you choose not to participate or withdraw after you have begun, but would like your 2% credit for participation, you may complete an alternative educational activity. The time it takes to complete this activity will take no longer than the time it takes to participate in this study.

Your decision to discontinue will not affect your academic status or access to services from the

University of Alberta. If you choose to participate, you may stop at any time and your data will be destroyed. Responses made by individual participants in this task will remain confidential, and your name will not appear or be associated with your data-file in any way. Only researchers associated with the project will have access to the data-files which will be stored securely on a computer with a password. The results of this study may be presented at scholarly conferences, published in professional journals, or presented in class lectures. Only grouped (aggregate) data will be presented. The data will be securely stored by Eric Legge and/or Dr. M[redacted] S[redacted] for a minimum of five years.

Alternative educational activity. If you decide right now that you would rather do the alternative educational assignment, please inform us, and I will give you an envelope with your assignment in it.

Benefits and risks. This research can potentially contribute to the advancement of our understanding of how certain people think about and solve problems in spatial tasks. There are no foreseeable risks to this study, but if any risks should arise, the researcher will inform the participants immediately. If you should experience any adverse effects, please contact Eric Legge, Dr. M[redacted] S[redacted], or Dr. T[redacted] J[redacted] immediately.

Contact information. If you have any questions or comments on the study, or if you wish a clarification of rights as a research participant, you can contact Eric Legge or the Human Research Ethics Committee at the number and address below.

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Signatures. Please sign below to indicate that you have read and understood the nature and purpose of the study. Your signature acknowledges the receipt of a copy of the consent form as well as indicates your willingness to participate in this study.

Participant's Signature _____ Date _____

Researcher's Signature _____ Date _____

Appendix E

Debriefing Form Example

An example of a debriefing form participants would receive after completing an experiment. This particular debriefing form was given to participants after completing Experiments 4a and 4b. Personal information such as names, email addresses, and phone numbers have been removed for privacy reasons.

Thank you very much for participating in our experiment. This experiment was designed to investigate the effect that differential outcomes have on locating a reward. In this experiment, there were two groups of participants: the differential outcome group and a control. If you were part of the differential outcome group, each landmark (the colored object) would correspond to a specific reward. If you were in the control group then the reward that you would obtain from each landmark would be randomly selected (i.e. a particular landmark would give you each reward randomly). Our hypothesis was that participants in the group that obtained differential outcomes for each item would be more accurate in their searches compared to the control group who did not receive this manipulation. Thus, our independent variable for this study was the group and the dependent variables were the search accuracy and reaction time.

This study is part of a series of experiments exploring how differential outcomes enhance memory when an individual (or animal) has to make a decision between two or more items in a task. There is a wide body of literature available that states that this

phenomena holds for a variety of tasks (i.e. delayed matching to sample) in a variety of species (e.g. humans, rats, pigeons, etc). One of the areas of study that research has not yet explored in this phenomena is in the spatial domain (ergo, the research study you have just participated in). I also have a study underway involving pigeons in an open-field and operant box analog of the task you just completed. Furthermore, there are more studies planned in the future.

This research is important for theoretical reasons and because knowledge about how spatial memory can be enhanced has practical implications especially in areas of mental health and behavior modification. In addition, there are a variety of studies in the literature that use spatial decision making models for the basis of their experiments (i.e. episodic memory studies) but yet they generally use the same type of rewards or a combination of rewards without considering how reinforcement consistency might affect their results. Thus, if our studies show this to be the case, then it will be an important advancement in how research is conducted and will raise attention to this possible role of differential outcomes.

As you can see, it is very important to have people participate in our research so that the scientific endeavor can progress. Your participation not only helps to advance science, but also leads you to understand how I go about conducting research so that I can address important psychological issues.

One additional thing that I want to discuss with you is why, in the beginning, I didn't explain exactly what our hypotheses were. If I told you that I were expecting you to perform more (or less) accurately because you were in a particular group, then it might have influenced your responding since you might have felt pressured to react in

the way you thought I expected you to on the basis of our theory rather than reacting the way you normally would. The possibility that some participants might react to independent variable manipulations based on what they believe the experimenters expect is called the *demand awareness effect.* This can be a problem in research because our results may not reflect the psychological processes that I are interested in studying, but could simply reflect *demand awareness.* If this was the case, scientific progress would be slowed and inappropriate avenues of research would be followed. So, I hope you can see how having people know our hypotheses in advance of responding would lead to problems in the interpretation of our data. I are sorry I couldn't tell you everything before; hopefully you can see that if I told you exactly what I were looking at, you might have responded a little differently. One thing that I need to ask you is that you don't tell other students what I were studying because, if they know it could affect their responses.

Thanks very much for participating. Without the help of people like you, I couldn't answer most important scientific questions in psychology. You've been a great help. Do you have any questions or concerns that I can answer right now? If you have any questions, later on, about the study or just general questions related to the issues I addressed here, contact Dr. S[redacted] at 492-[redacted]. Furthermore, the research participation coordinator, S[redacted] R[redacted], is available if you have any concerns. Her phone number and email are 492-[redacted] and [redacted]@ualberta.ca. Also, you may contact the research participation director, D[redacted] H[redacted], with your concerns. His phone number and email are 492-[redacted] and [redacted]@ualberta.ca.

And again, please don't tell other people about what I had you do in here

because I may be using others in your classes as participants. Once again, thanks for your help!